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WEATHER BUREAU

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MONTHLY WEATHER REVIEW

VOLUME 44, No. 3

MARCH, 1916

WASHINGTON
GOVERNMENT PRINTING OFFICE
1916

MARCH, 1916.

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NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the Editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for the illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Acting Editor.

VOL. 44, No. 3.
W. B. No. 577.

MARCH, 1916.

CLOSED MAY 3, 1916
ISSUED MAY 31, 1916

INTRODUCTION.

As explained in this Introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS to the MONTHLY WEATHER REVIEW will be published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Beginning August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observations by Weather Bureau observers and others as reported to the Washington office. Occasional original papers by prominent students of seismological phenomena.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.— *Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1915. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW but collected and published by States at selected section centers.

The data needed in section 7 can only be collected and prepared several weeks after the close of the month designated on the title page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belén College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

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SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING MARCH, 1916.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Weather Bureau, Washington, Apr. 22, 1916.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1916, **44**:2.

From Table 1 it is seen that the monthly means of direct solar radiation intensities were somewhat below normal for Washington, slightly above normal for Santa Fe, and decidedly above for Madison. A noon intensity of 1.63 calories, measured at Santa Fe on March 17, about equals any previous noon intensity measured at that station, and exceeds by 3 per cent any previous March measurement. Noon maxima of 1.58 calories at Madison on March 8, and 1.48 calories at Washington on March 16, do not differ materially from previous March maxima.

On March 8, 10, and 15, the measurements at Madison show unusually steady sky conditions, and extrapolated to zero air mass give values of 1.84, 1.83, and 1.84, respectively, when reduced to mean solar distance of the earth. On March 3, 7, and 17, the measurements at Santa Fe also show steady sky conditions. Extrapolated to zero air mass and reduced to mean solar distance they give values of 1.89, 1.88, and 1.84, respectively. Taken in connection with the vapor pressures of Table 2, these latter are in accord with values published in the REVIEW for September, 1915, **43**:440, Table 4, while those for Madison are slightly lower.

TABLE 1.—*Solar radiation intensities during March, 1916.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Mar. 4	.....	1.31	1.17	1.07	0.97	0.81	0.65	0.54	.....	.....
5	.....	1.21	1.10	.....	.....	.....	.....	.....	.....	.....
9	.....	1.27	1.18	1.08	0.97	0.87	0.79	0.70	0.64	0.59
11	.....	1.44	1.37	1.25	.....	.....	.....	.....	.....	.....
13	.....	.....	0.80	0.71	0.63	0.55	0.49	.....	.....	.....
16	.....	1.44	1.32	1.21	.....	.....	.....	.....	.....	.....
17	.....	1.46	1.26	.....	.....	.....	.....	.....	.....	.....
18	.....	.....	.....	.....	.....	1.00	0.90	0.85	0.79	0.71
20	.....	1.45	1.37	.....	.....	.....	.....	.....	0.98	0.93
23	.....	1.22	1.07	0.94	0.84	0.76	0.71	0.66	0.62	0.58
31	.....	1.23	1.12	1.04	0.96	0.87	0.80	0.75	0.70	0.65
Monthly means	.....	**1.34**	**1.18**	**1.04**	**0.87**	**0.81**	**0.72**	**0.70**	**0.75**	**0.69**
Departure from 9-year normal	.....	**+0.02**	**−0.01**	**−0.04**	**−0.11**	**−0.08**	**−0.09**	**−0.07**	**−0.01**	**−0.02**
P. M.										
Mar. 4	.....	.....	.....	1.11	1.01	0.91	0.83	0.76	0.71	0.67
8	.....	1.29	.....	.....	.....	0.75	.....	.....	.....	.....
9	.....	1.43	1.34	.....	1.16	1.09	1.03	0.97	0.93	0.90
11	.....	1.45	1.36	1.27	1.15	1.02	0.91	0.84	0.79	0.73
17	.....	1.13	1.06	0.98	0.84	0.72	.....	0.52	0.49	0.47
23	.....	1.18	0.98	0.85	0.76	0.70	0.67	0.64	0.57	0.51
31	.....	1.15	0.92	0.69	0.61	0.54	0.49	0.43	.....	.....
Monthly means	.....	**1.27**	**1.13**	**0.98**	**0.92**	**0.82**	**0.79**	**0.69**	**0.70**	**0.66**
Departure from 9-year normal	.....	**−0.04**	**−0.04**	**−0.06**	**−0.04**	**−0.06**	**−0.03**	**−0.04**	**±0.00**	**+0.01**

TABLE 1.—*Solar radiation intensities during March, 1916*—Continued.

Madison, Wis.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Mar. 7	.....	.....	.....	.....	1.21	.....	1.09	1.02	0.95	.....
8	.....	1.55	1.45	1.37	1.29	1.21	1.14	1.08	.....	.....
10	.....	1.52	1.44	1.35	1.27	1.21	1.15	.....	.....	.....
15	.....	1.57	1.49	1.40	1.33	1.25	1.19	1.14	.....	.....
Monthly means	.....	**1.55**	**1.46**	**1.37**	**1.28**	**1.22**	**1.14**	**1.08**	**(0.95)**	.....
Departure from 6-year normal	.....	**+0.11**	**+0.12**	**+0.09**	**+0.07**	**+0.08**	**+0.07**	**+0.03**	**+0.01**	.....
P. M.										
Mar. 3	.....	.....	1.41	1.37	1.30	1.20	1.04	.....	.....	.....
8	.....	1.60	1.50	1.41	1.34	1.27	.....	.....	.....	.....
10	.....	1.53	.....	.....	.....	.....	.....	.....	.....	.....
15	.....	1.58	1.50	1.42	1.33	1.27	1.20	1.14	.....	.....
Monthly means	.....	**1.57**	**1.47**	**1.40**	**1.32**	**1.25**	**(1.12)**	**(1.14)**	.....	.....
Departure from 6-year normal	.....	**+0.16**	**+0.12**	**+0.12**	**+0.06**	**+0.03**	**+0.02**	**+0.04**	.....	.....

Lincoln, Nebr.

A. M.										
Mar. 3	.....	1.55	1.47	1.38	1.28	1.19	.....	.....	.....	.....
7	.....	.....	1.49	1.37	1.29	1.21	1.14	1.08	1.02	.....
10	.....	.....	1.45	1.36	1.27	1.22	.....	.....	.....	.....
13	.....	1.39	1.35	.....	.....	.....	.....	0.88	.....	.....
17	.....	.....	.....	.....	.....	0.80	0.72	.....	.....	.....
18	.....	1.24	1.06	.....	0.93	0.83	0.75	0.69	.....	.....
28	.....	.....	1.30	.....	.....	.....	.....	.....	.....	.....
Means	.....	**1.39**	**1.35**	**1.37**	**1.19**	**1.05**	**0.87**	**0.88**	**(1.02)**	.....
P. M.										
Mar. 6	.....	.....	1.36	1.31	1.27	1.18	1.15	.....	.....	0.95
11	.....	1.34	1.28	1.16	1.08	1.00	0.93	0.86	0.80	.....
13	.....	1.41	1.28	1.18	1.06	0.95	0.87	0.80	0.73	.....
18	.....	.....	1.36	.....	.....	.....	.....	.....	.....	.....
22	.....	1.32	.....	.....	.....	.....	.....	.....	.....	.....
27	.....	1.45	.....	1.20	1.13	1.07	1.00	0.94	0.90	0.86
28	.....	1.38	1.24	1.14	1.05	0.96	0.88	.....	.....	.....
Means	.....	**1.38**	**1.30**	**1.20**	**1.12**	**1.03**	**0.97**	**0.87**	**0.81**	**(0.90)**

Santa Fe, N. Mex.

A. M.										
Mar. 3	.....	1.61	1.55	1.46	1.35	.....	1.33	1.27	1.21	.....
4	.....	1.53	1.42	.....	.....	1.19	.....	.....	1.06	.....
7	.....	1.63	1.53	1.44	1.37	1.32	1.26	1.19	.....	.....
10	.....	1.53	1.48	1.41	1.34	1.27	1.22	1.17	1.11	.....
11	.....	1.39	1.33	1.28	1.25	1.09	1.02	0.94	0.85	.....
14	.....	1.63	1.52	1.44	1.38	1.31	1.27	1.20	1.16	.....
15	.....	1.53	1.42	1.38	1.29	1.20	1.13	.....	.....	.....
16	.....	1.58	1.50	1.43	1.36	1.34	1.28	1.21	1.09	.....
17	.....	1.61	1.54	1.47	1.41	1.36	1.32	1.28	1.24	1.21
27	1.59	1.51	1.44	1.36	1.28	1.20	.....	1.06	.....	.....
Monthly means	**(1.59)**	**1.56**	**1.47**	**1.41**	**1.34**	**1.25**	**1.23**	**1.16**	**1.11**	**(1.21)**
Departure from 4-year normal	**+0.01**	**+0.05**	**±0.00**	**+0.01**	**±0.00**	**±0.00**	**±0.00**	**±0.00**	**±0.00**	**±0.00**

Skylight polarization measurements made at Washington on five days give a mean of 62 per cent. The maximum of 70 per cent, measured on the 9th, nearly equals the highest previous March reading of 71 per cent, measured in 1915.

TABLE 2.—*Vapor pressure at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a. m.	8 p. m.	Date.	8 a. m.	8 p. m.	Date.	8 a. m.	8 p. m.	Date.	8 a. m.	8 p. m.
1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*
Mar. 4	0.152	0.300	Mar. 3	0.096	0.079	Mar. 3	0.079	0.226	Mar. 3	0.160	0.206
5	.315	.132	7	.168	.262	6	.536	.381	4	.262	.345
8	.345	.206	8	.124	.145	7	.330	.262	7	.196	.196
9	.137	.168	10	.168	.178	10	.300	.226	10	.381	.287
11	.160	.168	15	.107	.137	11	.274	.627	11	.399	.226
13	.381	.602				13	.417	.516	14	.178	.102
16	.132	.137				17	.330	.536	15	.226	.206
17	.249	.145				18	.437	.363	16	.196	.152
18	.102	.188				22	.437	.315	17	.160	.216
20	.168	.178				27	.345	.417	27	.274	.206
23	.249	.249				28	.417	.536			
31	.475	.627									

Table 3 shows that at Washington the total solar and sky radiation was considerably below the normal during the first and third decades of March, and somewhat above normal during the second decade. The deficiency for the month is 12.6 per cent of the average March radiation, and the deficiency since the first of the year is 9.6 per cent of the average.

While, therefore, during the first three months of 1916 direct solar radiation intensities with clear skies have been fully equal to the average for the season, at Washington the total radiation has shown a deficiency, due to more than the average cloudiness.

TABLE 3.—*Daily totals and departures of solar and sky radiation at Washington, D. C., during March, 1916.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.	Departures from normal.	Excess or deficiency since first of month.
1916.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Mar. 1	319	12	12
2	224	− 86	− 74
3	102	−211	− 285
4	414	98	− 187
5	442	123	− 64
6	57	−264	− 328
7	205	−119	− 447
8	301	− 25	− 472
9	485	156	− 316
10	92	−239	− 555
Mar. 11	516	182	− 373
12	333	− 3	− 376
13	273	− 66	− 442
14	283	− 58	− 500
15	35	−308	− 808
16	505	159	− 649
17	526	178	− 471
18	327	− 23	− 494
19	467	114	− 380
20	507	152	− 228
Decade departure			327
Mar. 21	216	−141	− 369
22	70	−290	− 659
23	526	164	− 495
24	311	− 53	− 548
25	374	8	− 540
26	435	66	− 474
27	76	−295	− 769
28	56	−317	−1,086
29	70	−305	−1,391
30	267	−111	−1,502
31	536	156	−1,346
Decade departure			−1,118
Deficiency since first of year:			
Gram-calories			2,247
Per cent			9.6

CONVECTION IN UPPER REGIONS OF SUN'S ATMOSPHERE.[1]

By F. HENROTEAU.

[*Reprinted from* Science Abstracts, Sect. A, Feb. 28, 1916, §168.]

From a study of spectroheliograms taken with sufficiently high dispersion to separate the higher layers of the solar atmosphere Deslandres has shown that the filaments often group themselves on a curve encircling the pole at distances varying from 50° to 70° heliographic latitude. These polar curves of filaments are in general more developed in the hemisphere, or on the meridians, where spots and faculæ are relatively feeble, and appear to be more pronounced in years of minimum spot activity. Further, they show evidence of being in general ascending currents while the spots and faculæ are regions of descent of the vapors concerned. The present author examines the evidence for detecting any existent convection currents which might be produced as the result of this difference of atmospheric pressures. Visual observations of faculæ provide some confirmation. Other verification is furnished by the motions of prominences recorded by Slocum from measurements of photographs taken with the Yerkes spectro-heliograph. At mean latitudes there is a tendency of movement toward the poles; in high latitudes the movement is generally toward the Equator. Reproductions of drawings of spots and faculæ, made at Stonyhurst are included to illustrate the phenomena described.—*C. P. B[utler]*.

SEESAW OF PRESSURE, TEMPERATURE, AND WIND VELOCITY BETWEEN WEDDELL SEA AND ROSS SEA.[2]

By R. C. MOSSMANN.

[*Reprinted from* Science Abstracts, Sect. A, Jan. 21, 1916, §19.]

Four years' data are discussed in three-months groups. The observations refer to M'Murdo Sound (Ross Sea) on the one hand and to stations in the South Orkneys and Grahams Land (Weddell Sea) on the other. The difference in longitude between the two districts is about 120°. It is found that seasonal departures from the normal of barometric pressure are of opposite sign in the two areas, out of the 16 seasons discussed there being only 3 in which the divergences are of the same sign. The wind-velocity variations show a similar seesaw effect. As regards temperature there is pronounced opposition in the departures for the winter season, but for the other periods of the year the results are indefinite. In the later part of the paper conditions at M'Murdo Sound are compared with those at stations in temperate latitudes widely separated from it, and certain similarities and oppositions in the fluctuations are found. Great changes occur from year to year or between groups of years in the Antarctic circulation. Thus the mean wind velocity in M'Murdo Sound during Scott's first expedition (1902–1904) was only half that recorded during the second expedition (1911–12), and from the Weddell Sea data it appears that storms were frequent and violent from 1902 to 1906, while from 1907 to 1914 few have been experienced.—*J. S. D[ines]*.

[1] *See* Mo'ly. notices, Roy. astron. soc., Nov., 1915, **76**: 18–22.
[2] *See* Proc. Roy. soc. Edinburgh, 1914–15, **35**: 203–216.

ATMOSPHERIC POLLUTION IN ENGLISH AND SCOTTISH TOWNS.[1]

By J. B. C. KERSHAW.

[*Reprinted from* Science Abstracts, Sect. A, Jan. 31, 1916, §21.]

Observations with a standard type of dust-and-soot-collecting gage (see Abstract 1209B, 1913) have been made in 16 towns for a period, in most cases, of over one year. The figures obtained are summarized in a table. The largest soot and dust fall is recorded from Oldham, with 31.2 metric tons per square kilometer per month. Manchester (Ancoats) comes second, 26.8 metric tons, whereas Malvern shows only 2.1 metric tons. The Oldham fall is equivalent to 957 [Brit.?] tons per square mile per annum. Another table sets out the proportions of the insoluble deposits—tar, carbonaceous matter, and ash. Figures which have been given for the soot and dust fall of Pittsburgh (33.6 metric tons per square kilometer per month) show that the amount deposited there is considerably in excess of the amount in Sheffield (21.7 metric tons/km²/mo.), the English steel-making center. It is suggested that observations made on the Rotherham side of Sheffield might have approximated more closely to those of Pittsburgh, the prevailing winds carrying the smoke to the Rotherham side of the city. A special type of recording actinometer, which has been devised for measuring the intensity of sunlight illumination and used in different parts of Manchester, is described and illustrated. The record is made on specially prepared photographic paper. It was found that the average intensity of sunlight on the roof of the School of Technology (100 feet high) was 12.6 per cent greater than that at the ground level. Measurements with this actinometer are also to be made for comparative purposes in Abergele, in North Wales, away from the polluted atmosphere of towns.—*J. S. D[ines]*.

[1] *See* Engineer, London (?), Nov. 19, 1915, **120:** 473-475; Metall. and chem. eng., Dec. 15, 1916, **13:** 967-971.

ATMOSPHERIC POLLUTION.[2]

By W. P. WYNNE.

[*Reprinted from* Science Abstracts, Sect. A, Feb. 28, 1916, §218.]

Monthly results of the chemical examination of rain water collected at four sites in Sheffield have been published. They do not accord with expectation and certain conclusions have been reached regarding the effectiveness of this method of measuring atmospheric pollution, which are of more than local interest. The records cover the period July, 1914, to June, 1915, and the results for the four stations are shown on two diagrams, one giving the monthly measurements of insoluble matter in the collected rain water and the other of dissolved matter. It appeared probable that the amount of dissolved matter measured in any month would depend on the amount and duration of rainfall in that month. The monthly rainfall at one of the stations (Attercliffe) has been plotted upon the same diagram as the amount of dissolved matter, and close agreement is apparent between the two curves. A similar diagram is shown for Malvern, and the similarity of the two curves is even more marked. It is concluded that the method of measurement usually adopted does not afford a reliable indication of the real degree of atmospheric pollution and that better results might be obtained if a feasible method could be devised for drawing air continuously through water and measuring the amount of the impurities extracted in this way.—*J. S. D[ines]*.

[2] Read before the Manchester meeting of the British Association for the Advancement of Sciences. Abstracted in Nature (London), Dec. 16, 1915, **96:** 442-444.

SECTION II.—GENERAL METEOROLOGY.

SOME PROBLEMS OF ATMOSPHERIC ELECTRICITY.

By GEORGE C. SIMPSON, D. Sc., F. R. S., vice president.

(Read before the Physics Section, Indian Science Congress, Lucknow, January, 1916.)

[Dated: Meteorological Department, Simla, India, Feb. 25, 1916; received, Mar. 31, 1916.]

The problems of atmospheric electricity with which we are about to deal must be solved by means of the laws which govern the behavior of electricity in gases, and I therefore propose, before discussing the actual conditions, to sketch in a few words the main principles involved.

The earth is a solid body which for all purposes of atmospheric electricity may be considered to be a perfect conductor. Its dimensions are so large, and therefore its electrical capacity so great, that no amounts of electricity which we can extract or add at any place can alter its electrical potential. As the potential of the earth does not change, it is convenient to take its potential as our standard and refer all other potentials to it. We therefore describe the earth as being at zero potential and the potentials of all other bodies as plus or minus the difference between the potential of the body and the earth.

Let us suppose that the earth has no atmosphere, and we give to it a charge of electricity which, in order to fix our attention, we will assume to be negative, then by the laws of electrostatics the charge would distribute itself all over the surface. If the surface were a perfect sphere, the surface distribution would be everywhere the same; but as there are irregularities, every hill would have an excess of electricity and every valley a defect. The value of the surface density at any point could easily be measured. An ideal, although not a practical, method to do this would be to take a unit charge of positive electricity and hold it at a certain distance from the earth. The negative charge on the earth would then attract our positive charge, and if we moved the latter away from the earth's surface we should have to do work. If we moved the charge from the ground to a meter above the ground, we should do against the electrical forces an amount of work equivalent to the electrical potential energy of the charge at 1 meter above the ground. More work would have to be done to convey the charge to 2 meters, and still more to 3 meters. At every position, then, above the surface our unit charge would have a different potential. From this experiment we could calculate the change in potential of our unit charge at every position above the surface, and it would be a simple matter, by the laws of electrostatics, to calculate from this change of potential, or, as it is called, the potential gradient, the amount of charge on the earth's surface. It is important to realize that when we measure the potential gradient immediately above the earth's surface we are only finding the force due to the electricity spread over the ground.

Now, let us imagine that an atmosphere is given to the earth, and see what consequences we might expect. For long it was supposed that air was a perfect nonconductor of electricity, and we will for a short time retain this false impression. A nonconducting atmosphere at rest would not affect the electrical state of the surface and we should still be able to measure the amount of charge by measuring the potential gradient. If, however, the air moves and we get winds, the electrical state of the surface may be greatly affected. I have explained how the whole charge on the earth is situated on the upper surface of the ground; hence every particle of dust, every blade of grass, and every leaf of a tree has a charge of electricity upon its surface. If, therefore, the wind raises the dust (we are to neglect any frictional electricity produced by the process) or whirls away the leaves of a tree, a certain amount of electricity is separated from the earth and raised into the air. But so long as the air is nonconducting the charge remains fixed onto the dust and onto the leaves, so that when the wind stops and they fall to the ground again the charge is returned to the surface of the earth. With a nonconducting atmosphere the charge on the earth can not be permanently separated, and after any length of time we should still find the same quantity of electricity from our measurements of the potential gradient.

But recent research has shown that air is not a perfect nonconductor; it conducts electricity slowly, but as surely as copper conducts it. Electrically a conducting atmosphere becomes a part of a conducting earth, and just as before there was an atmosphere electrostatic forces drove all the electricity up to its surface, the same forces will drive it through the air until it reaches the surface of the conducting sphere which is now the confines of the conducting atmosphere. All our electricity then will ultimately spread itself in a uniform layer over the outside of the atmosphere. Now, it is well known that there is no electrical force within a conductor no matter how much electricity there may be on the surface. Therefore no experiments that we can make at the surface of the earth would reveal the charge spread over the upper atmosphere. It is important to realize that there may be a charge of untold amount in the upper atmosphere of which we are entirely ignorant because of this property of a conducting body to exhibit no electrical force within itself.

It therefore appears that it would be impossible for a charge to remain on the surface of the earth while the air is ever present to conduct it away into the upper atmosphere. Yet we find that the whole surface of the earth is charged and remains charged with an undiminishing quantity of electricity. This is a paradox about which I shall have a great deal to say later, but before discussing it, it will be necessary to go more fully into the causes of the conductivity of the air.

The conductivity of the air is a very variable quantity, its average value is near to 3×10^{-4} electrostatic units, which means that its resistivity is 3×10^{7} ohms or twenty thousand million (2×10^{10}) times that of copper. The mechanism of the conductivity in copper and air are, however, very different. The air conducts only when its molecules are ionized; that is, split up into positive and negative ions which move under the influence of the electrical field. Thus, when a current of electricity passes through conducting air there is an actual transferrence of matter, while in copper the electricity moves independently of the mass of the copper.

1. RADIOACTIVE SUBSTANCES AND ATMOSPHERIC IONIZATION.

Observations in all parts of the world have shown that the atmosphere everywhere is ionized and it is generally held that the radioactive substances in the earth and air are the cause of this ionization. The first question which I wish to discuss is whether this radioactive theory of the ionization of the air is alone capable of explaining the facts.

To do this we will first consider the ionization actually found by experiment over the land and over the sea, then the number of ions formed by the known radioactive matter over the land and over the sea, and lastly whether these values agree.

The ionization, over the land particularly, is greatly affected by the meteorological conditions, the chief factor being the temperature. We shall therefore in the following only consider the ionization with temperatures between 10° and 20°C. Very many measurements of the ionization have been made and these show that within the limits of temperature we are considering, there are on the average over the land 1,000 ions of each sign in each cubic centimeter of air.

The measurements over the sea are much less numerous, but when on a voyage from England to New Zealand Wright and I[1] made a number of determinations of the ions present over the ocean far from land, and the mean value of sixteen observations with the temperature between 10° and 20° C. was 800 ions per cubic centimeter.

We therefore have over land 1,000 and over the ocean far from land 800 ions per cubic centimeter.

We will now turn our attention to the radioactive matter which is supposed to be capable of producing this ionization.

It is now definitely known that the rocks of the earth's crust contain appreciable amounts of radium and thorium, and numerous measurements of the radioactive contents of the rocks have shown that this radioactive matter is present in nearly all kinds of rocks and fairly uniformly distributed throughout all soils. The radioactive matter in the ground produces α, β, and γ rays, but the two former do not escape into the atmosphere, except in a negligibly small proportion from the actual surface, and therefore cannot effect ionization there. On the other hand, owing to their greater penetrating power, a certain proportion of the γ rays do pass out of the ground into the air and ionize it. These rays are absorbed in the air and therefore the ionization due to them decreases as we ascend but giving our attention to the air near the surface, say, within 6 feet, a simple calculation[2] shows that the average amount of radium in the soil gives out sufficient γ radiation to produce 0.8 ion per cubic centimeter per second. The amount of thorium is not known with such accuracy, but it is generally supposed that the ionizing power of the thorium in the soil is about equal to that of the radium. Hence the thorium and radium in the soil combined produce by means of their γ radiation something like 1.6 ions per cubic centimeter per second in the air just above the ground.

The radium and thorium in the soil are constantly giving off their respective emanations. These emanations fill the interstices of the soil, from which they escape into the atmosphere by ordinary diffusion and in consequence of any fall of barometric pressure. Thus the air over the land receives emanations from the ground which behaves very much like one of the ordinary gases of the atmosphere except that it is constantly decaying owing to radioactive change.

This emanation or radioactive gas is constantly emitting α, β, and γ radiations and in consequence ionizing the air. In this case all three kinds of radiation are in a position to ionize the air and we are able to form some idea of the magnitude of the effect. The calculations of Eve[2] show that the actual radiation from each of the emanations in the air produces the ions given in Table 1.

TABLE 1.—*Ions per cubic centimeter per second produced in the atmosphere by the different emanations in the air.*

Rays.	Radium.	Thorium.	Total.
	Ions/cc., sec.	*Ions/cc., sec.*	*Ions/cc., sec.*
α	1.63	1.00	2.63
β	0.035	0.025	0.06
γ	0.035	0.025	0.06
Total	1.70	1.05	2.75

It will be seen that the ionization due to the emanation in the air is mainly caused by the α rays.

We can now state how many ions are produced each second in a cubic centimeter of the air near the ground by the radium and thorium in the earth and air.

TABLE 2.—*Ions per cubic centimeter per second produced in the air near the ground by the radium and thorium in both earth and atmosphere.*

Sources of rays.	Radium.	Thorium.	Total.
	Ions/cc., sec.	*Ions/cc., sec.*	*Ions/cc., sec.*
Air	1.70	1.05	2.75
Earth	0.80	0.80	1.60
Total	2.50	1.85	4.35

Thus the best estimates show that in each cubic centimeter of air over the land there are 4.35 ions of each sign generated every second.

Similar considerations can be applied to find the number of ions generated by radioactive matter over the ocean. We have the radioactive matter in the sea and the emanation in the air. The radioactive matter in the sea itself is so small that it can not produce by means of its γ rays more than 0.01 ion per cubic centimeter per second in the air over the sea. Also the emanation given out from the sea is so minute that it can be neglected, therefore if there is any emanation in the air over the sea it must have been brought from the land by the winds. This makes it impossible for there to be any appreciable thorium emanation over the oceans, for thorium emanation reduces to half value in less than a minute and it would therefore have entirely disappeared before the wind could have carried it far from the land.

We are, therefore, left with radium emanation only in the air over the sea. Naturally the amount of radium emanation over the sea has not been determined to anything like the same extent as it has over the land. But we know that it is very much less. At Hammerfest, in Norway, I found[3] that when the wind blew from the west, i. e., from the Atlantic Ocean, the radium it contained was only a little more than a twentieth part of the amount brought from inland by southerly winds.

[1] Simpson & Wright *in* Proc. Roy. soc., London, 1911, **85A**: 175.
[2] Eve *in* Phil. mag., London, 1911, **21**:26.
[3] Simpson *in* Phil. trans., Royal soc., 1905, **205A**: 61.

During the voyage already referred to Wright and I measured the radioactivity of the air over the Atlantic and southern Indian Oceans far from land. When we arrived at South Africa the apparatus we had used on the ship was taken 200 miles inland. It was found that the radium collected inland was twenty times that collected over the ocean.

These experiments indicate, then, that over the ocean there is only 5 per cent of the radium emanation found over the land, but as other observers have found slightly higher values we will assume that there is 10 per cent. Thus, the radium in the air over the ocean can produce at the most only a tenth of the ions produced by the radium over the land.

We therefore are justified in constructing for the ocean the following table to compare with Table 2 for the land.

TABLE 3.—*Ions per cubic centimeter per second produced in the air near the surface of the sea by the radium and thorium in both air and sea.*

Source of rays.	Radium.	Thorium.	Total.
	Ions/c. c., sec.	*Ions/c. c., sec.*	*Ions/c. c., sec.*
Air	0.17	0	0.17
Sea	0.01	0	0.01
Total	0.18	0	0.18

Thus, using the most liberal estimate, all the known radioactive matter over the sea is able to produce only 0.18 ion per cubic centimeter per second.

Collecting our results, we have Table 4.

TABLE 4.—*Total numbers of ions per cubic centimeter present and being generated per second.*

Locality.	Number of ions per cubic centimeter. (n)	Number of ions generated per cubic centimeter per second by radioactive matter. (q)
Over land	1,000	4.35
Over ocean	800	0.18

We must now examine whether the number of ions generated in each case is capable of maintaining the number of ions actually found.

If every ion formed in the atmosphere remained an ion we should have an ever increasing number; but we know that when a positive and a negative ion meet they recombine to form a neutral molecule. It is obvious that the more ions there are in a given volume the more rapidly they will join together, and it is easily shown that for the steady state we have the folowing relationship:

$$q - \alpha n^2 = 0$$

in which q is the number of ions of each sign formed each second, n the number of ions of each sign present and α the coefficient of recombination. This equation simply means that for the steady state the number of ions formed in a second, q, is equal to the number of ions which recombine in a second.

If we can determine α for the land and the sea we shall be able to decide whether the values of n and q given in Table 4 are consistent. The rate of recombination of ions has been determined by several observers. The method used has been to ionise air by some outside ioniser, X rays or Becquerel rays, then to remove the ioniser and determine the decrease in ions due to recombination after definite intervals of time.

Before discussing the results of these measurements, we must say something about the factors on which the rate of recombination depends. If an ion comes near to matter, say the wall of the vessel containing the air, it induces a charge on the wall and the electrical force so produced causes the ion to attach itself to the wall and it is lost. In the same way ions attach themselves to any dust floating in the air and in consequence lose their property of moving freely in an electric field; again these are lost to measurement. It is found that water vapor tends to attach itself to ions and in consequence the ions lose their mobility in a damp atmosphere. Thus, dust and damp in the air have the apparent effect of increasing the rate of recombination of ions, hence we should expect the rate of recombination to be least in dry, dust-free air, greater in damp air, and greatest in damp and dusty air.

Experiments have confirmed this conclusion, and the values of α found have been—

(a) in dust-free dry air, 1.5×10^{-6} (Townsend[4]).

(b) in the air in the outskirts of Vienna, 3×10^{-6} (Mache & Rimmer[5]).

(c) in the dusty and damp winter air of Manchester, 4×10^{-6} (Schuster[6]).

In order to arrive at a definite conclusion, we ought to have made our determinations of n, q, and α simultaneously. As, however, this is impossible, we must choose from the above values of α the most probable value for the conditions under discussion.

We can say at once that α both over the sea and land must be greater than the value found for dry dust-free air. As the values of n for the land given above were determined in pure country air, we can say equally definitely that α must be less than the value found during winter in Manchester. Also, it is probable that α is greater over the land than over the sea.

It therefore seems reasonable to take α over the land as 3×10^{-6} and α over the sea as 2×10^{-6}.

With these values of α and the rates of generation of ions given in Table 4, we find from the equation

$$n = \sqrt{\frac{q}{\alpha}}$$

that if the whole ionisation were due to the radioactive matter known to be present, the air over the land should contain 1,200 ions per cubic centimeter, and the air over the sea only 300 ions per cubic centimeter.

Comparing these numbers with those given in the second column of Table 4, we see that the radioactive matter over the land is quite sufficient to account for the ionisation found there; but this is far from being the case over the ocean, where there are nearly three times as many ions as can be accounted for by the radioactive matter present.

It therefore appears that over the ocean at least the radioactive theory of the ionisation of the air is not satisfactory. This, then, is the first unsolved problem that I wish to bring forward for discussion.

[4] Townsend *in* Phil. trans., Royal Society, 1899, A193: 157.
[5] Mache & Rimmer *in* Physik. Ztschr., 1906, 7: 617.
[6] Schuster *in* Mem., Manchester litt. and Phil. soc., 1904, 48, Mem. 12.

2. EARTH'S PENETRATING RADIATION.

My second problem is generally described as the problem of the earth's penetrating radiation.[7]

If a closed metal box of suitable dimensions is cleaned with the greatest care so as to remove all radioactive matter from the inside, and if it is filled with air from which all radioactive matter has been removed by passing it through liquid air, it is found that the air within still has a residual ionization.

This in itself would not be very surprising, for it might be due to some small radioactivity of an impurity in the walls of the box, or even to some general radioactive property of all matter. What is surprising is that even when the box is kept at a constant temperature and hermetically sealed, the ionization within undergoes large changes both when the box is moved from place to place and also when it is kept in one place without being disturbed.

It is obvious that such changes must be due to a radiation entering the box from the outside, and as the walls are always too thick to allow either α or β radiation to enter, the radiation must be of the γ type.

We know of only two sources of γ radiation: The radioactive matter in the ground and the radioactive emanation in the atmosphere. The latter, however, can be ruled out at once for, as we see from Table 1, it can produce at the most only 0.06 ion per cubic centimeter per second, which is a quantity far too small to measure.

On the other hand the known radium and thorium in the ground are able by their γ rays to produce 1.6 ions per cubic centimeter per second, which amount may be largely exceeded in places where the ground is unusually rich in radioactive matter.

Neglecting, then, the ionization which is characteristic of the instrument and can not vary, we know of only one source of radiation which enters the instrument from the outside and can vary from place to place and time to time. This source is the radioactive matter in the rocks and soil.

The γ radiation from the rocks and soil although relatively very penetrating has an appreciable absorption coefficient. It is entirely cut off by less than 1 meter of water and is rapidly absorbed by the air. Eve [8] has calculated that at an elevation of 100 meters the radiation from the ground should be diminished by 36 per cent and it should have disappeared entirely at an elevation of 1,000 meters.

One would conclude from this, therefore, that if we measure the ionization within our vessel over the land, then remove it to a place far removed from rocks and soil, as, for example, to a place over deep water or to a place 1,000 meters in the air, the ionization within the box would decrease by the amount due to the radiation from the earth. Also as the remaining ionization would then be due to the instrument itself, one would conclude that it could not be decreased further.

Such experiments have been made by many observers, but not with this expected result.

When the apparatus has been removed from the land over deep radium-free water a decrease in the ionization has been found, the average decrease being about 3 ions per cubic centimeter per second which is of the order we should expect. If the apparatus is now sunk into the water, a further unexpected decrease takes place, the new decrease (2 ions per cubic centimeter per second) being only slightly less than the previous one.[9] It appears then that by sinking the apparatus into the water we are cutting off another radiation which can only come from above, and is nearly as strong as that due to the radioactive matter in the soil.

Similar experiments have been made on land by building screens of lead about the apparatus, and these have also shown that some radiation apparently comes from above as well as from the ground.[10]

The results attained by taking the apparatus up into the air are also important. As has been already pointed out, if the penetrating radiation came only from the ground it would be rapidly cut off by the air and at 100 meters it would be reduced by 36 per cent.

Many observations have been made on towers and all have shown that the decrease of ionization within the apparatus is much less than the theory requires. A typical example is a set of observations made by Wulf [11] at 300 meters on the Eiffel Tower. The ionization was only reduced by 40 per cent, while according to Eve's calculations it should have been reduced by more than 90 per cent.

Such observations are, however, not satisfactory, as the towers may possibly have a considerable deposit of radioactive matter upon them which might be the cause of some increase of ionization.

Observations in free balloons, however, are free from this objection, and quite a number of these have been made.[12] They all agree in showing a much smaller decrease in the penetrating radiation with ascent than would be given by radiation from the ground only.

The balloon observations, however, go much further; they show that after about 2,000 meters the decrease with ascent ceases and the radiation commences to increase. At first the increase is slow and at 3,000 meters the ionization has returned to the value found on the ground. This increase with the height above sea level has also been found by Gockel [13] to occur when observations are made on glaciers in the Alps. There can, therefore, be little doubt as to the reality of the effect. As one ascends still higher a strange phenomenon is observed: The rate of increase of the radiation goes up by leaps and bounds. At 4,000 meters there are produced each second 9 ions more than on the ground; at 5,000 meters 19, and at 6,000 meters 30.[14] It appears from all these observations that in addition to the γ radiation from the earth there is another radiation coming from the sky. Sinking the apparatus in water shows that at sea level the sky radiation can produce 2 ions per cubic centimeter per second and is therefore nearly equal to that from the rocks and soil. Further, the balloon observations show that this radiation increases with height. At first, however, as one ascends over the land the total ionization within the box decreases owing to the cutting off of the radiation from the ground, so that at 2,000 meters the ionization is somewhat less than on the ground; above this the radiation increases rapidly and at 6,000 meters it is

[7] A good résumé of this subject, up to 1912, is given by *Chauveau* in Annuaire, Soc. météorol. de France, Paris, oct.-nov., 1912.

[8] Eve *in* Phil. mag., London, 1911, **21**: 26.

[9] Gockel *in* Physikal. Ztschr., 1915, **16**: 345.

[10] Cooke *in* Phil. mag., London, 1903, **6**: 403.

[11] Wulf *in* Physikal. Ztschr., 1910, **11**: 811. Also see last paragraph of Eve in Phil. mag., loc. cit.

[12] Hess *in* Wien. Ber., 1912, **121**: 2001.
Kolhörster *in* Physikal. Ztschr., 1913, **14**: 1066, 1153.

[13] Gockel *in* Physikal. Ztschr., 1915, **16**: 345.

[14] I see, from a reference in a recent paper by Gockel, that 80 ions per second have been observed at 9,000 meters; but I have not yet been able to see the original communication.—*G. C. S.* [Cf. Abstract of Kolhörster's paper, MONTHLY WEATHER REVIEW, Dec. 1915, **43**: 596.—ED.]

more than ten times as much as that due to the radioactive matter in the ground, and still greater values are found at greater heights.

What can be the source of this radiation? Two suggestions have been made. *First*, that there is an unknown radioactive gas in the air which is mainly confined to the upper atmosphere. *Second*, that a true penetrating radiation enters the atmosphere from cosmical space.

It would take me too long to discuss all the pros and cons of these suggestions. It is sufficient to say that both are highly improbable on our present knowledge, although perhaps not impossible.

Here is a field for research which holds out great possibilities; but I am afraid that it is one which will not be investigated further at present. Germany up to the present has been practically the only country which has made atmospheric-electricity observations from balloons, for in recent years ballooning has been a popular sport in that country. This sport was no doubt fostered by its military associations, and it is very unlikely that it will survive the great war. Ballooning is an expensive pastime and it is unlikely that after the war any European nation will have money to spare for the purpose. India is unsuitable for ballooning, so we have practically only America to look to for the investigation of this interesting question. Let us hope that observation will soon be made in that country.

This, then, is our second problem: What is the origin of the penetrating radiation which produces 2 ions per cubic centimeter per second within a closed box at sea level, and very many more as one ascends into the upper atmosphere?

3. THE ORIGIN AND MAINTENANCE OF THE EARTH'S CHARGE.

We must now leave the subject of the ionization of the air, its magnitude and cause, which has given us two important unsolved problems and return to our consideration of the charge on the earth which was the starting point of our discussion.

The problem that I intend to consider next is the origin of the charge on the ground and how it is maintained.

It has already been stated that the charge on the earth is measured by the potential gradient that it produces, and observations of the potential gradient have shown that during fine weather every part of the earth's surface, sea, land, plain, and mountain, from north polar regions to south polar regions, has a negative charge which is fairly constant except where the shape of the land causes local excesses or defects.

The potential gradient has also been measured in the upper atmosphere,[15] and it has been found that it decreases rapidly, so that at about 3,000 meters the field is only a tenth of what it is near the ground. This change in the field in a vertical direction can only be due to the air containing free positive electricity, which counterbalances the negative charge on the ground. The potential gradient continues to decrease slightly to the highest altitudes reached, and if, as is generally assumed, it disappears entirely at great altitudes this can only mean that the whole of the positive charge corresponding to the negative charge on the surface is contained in the air. The natural inference is that the electrical field in the atmosphere is due to some process which has separated the negative electricity on the surface from the positive in the air.

It is not sufficient for this process to have caused the separation once for all, for on account of the air being a conductor a current of electricity is set up between the charge on the earth and the charge in the air which tends to neutralize the charges and to cause the field due to them to disappear. That this current actually exists can be shown by insulating a portion of the earth's surface and measuring the actual amount of electricity which leaves it each second.[16] It is then found that the loss from the surface is exactly the amount which is calculated for the current caused by the potential gradient and conductivity of the air.

The loss which thus constantly takes place on account of the conductivity of the atmosphere must be constantly replaced, and as long as we hold that the positive charge in the air and the charge on the ground are complementary the process which maintains the charges and field must be sought mainly in the lower atmosphere, where the large proportion of the separated charge exists.

Numerous suggestions have been made to explain the maintenance of the field in spite of the constant neutralizing current, and they can all be divided into two classes:

(*a*) Suggestions which suppose the electricity to be separated in the air and the negative electricity to be carried by some mechanical means to the ground, leaving the positive charge in the air; and

(*b*) Suggestions which suppose the separation to take place at the earth's surface, which retains the negative charge while the positive charge is carried to the upper atmosphere in ascending air currents.

I think it is worth while to give an example from each of these classes.

The first and most important theory is generally called the Wilson-Gerdien theory.[17] According to this theory negative ions are nuclei, on which water vapor is readily deposited; hence when it rains the negative ions are carried to the ground with the rain drops. Thus every rain shower has been looked upon as carrying negative electricity from the air to the ground, and so maintaining the electrical field in the atmosphere.

This theory received a fatal blow when it was found that rain in all parts of the world carries down more positive than negative electricity.

Ebert's theory is a good example of the second class,[18] and deserves to be specially mentioned as it is still seriously maintained by a large proportion of German physicists. Experiment shows that when ionized air is passed through conducting tubes, the air under certain conditions emerges with more positive than negative ions. Applying this to the earth, Ebert says that the interstices in the soil are all full of radium emanation; hence the air in the soil must be highly ionized. When the barometer falls, this highly ionized gas streams into the atmosphere through all the channels and cracks in the soil, which are equivalent to the tubes used in the laboratory. Hence the air will emerge with a charge of positive electricity which is rapidly disseminated throughout the atmosphere by ascending air currents.

The fallacy of this reasoning has been pointed out,[19] but it does not appear to have convinced Ebert's disciples.

[15] Linke *in* Abhandl. d. königl. Gesellsch. d. Wissensch. zu Göttingen, 1904, III, No. 5.

[16] Wilson, C. T. R., *in* Proc., Royal soc., 1908, **80A:** 537.
Simpson, George C., *in* Phil. mag., London, 1910, **19:** 715.

[17] Gerdien *in* Physikal. Ztschr., 1905, **6:** 647.
Simpson *in* Phil. mag., London, 1909, **17:** 619.

[18] Ebert *in* Physikal. Ztschr., 1904, **5:** 135; Meteorol. Ztschr., 1904, **21:** 201.

[19] Simpson *in* Physikal. Ztschr., 1904, **5:** 325, 734.
Gerdien *in* Physikal. Ztschr., 1905, **6:** 654.
Ebert *in* Physikal. Ztschr., 1904, **5:** 499; 1905, **6:** 825, 828.

The interstices in the soil are so very small that in spite of the emanation there can be no high ionization, for the ions are absorbed by the walls at once. Also the rate of flow through the channels and cracks due to a falling barometer is so small that the air emerges with neither positive nor negative ions, for the laboratory experiments show that the ionized air must travel relatively rapidly through the tubes if the air is not to be robbed of all its charge in the passage.

This is not the place to go into details of what has proved to be a long and unsatisfactory controversy. I shall therefore content myself by stating that no process has been suggested to account for the separation of the charge in the air from the charge on the ground.

I now propose to show that the charge in the air is not the charge which has been separated from the electricity on the surface, and therefore it is useless to look for a process which constantly effects such a separation.

I have already stated that the loss from the surface is in accordance with the current which can be calculated from a knowledge of the potential gradient and the conductivity of the air just above the surface. Measurements have been made of both these factors by Gerdien [20] to a height of 6,000 feet (1,828.8 meters), and it is found that in all heights of the atmosphere the potential gradient multiplied by the conductivity is a constant. In other words the same vertical current is present throughout the atmosphere up to the greatest height reached by balloons carrying measuring instruments.

Now, as the same vertical current is present in 6,000 meters as on the ground, this means that none of the negative charge which left the ground has combined with the positive electricity in the air. This leads to the important conclusion that the negative charge on the surface and the positive charge in the air are not complementary in the sense that one has been extracted from the other. The relationship between these two charges will now be explained.

Let us imagine that by some means the earth is receiving a constant supply of negative electricity. We need not consider how this is effected; we are only concerned with the supposition that negative electricity is set free at a constant rate on the earth. This charge immediately spreads uniformly over the whole surface and sets up in the atmosphere a vertical electrostatic field. In this field the ions of the atmosphere move and so conduct a certain amount of the charge received by the earth into the upper atmosphere. In other words, under the laws of electrostatics the charge passes on to the outside of the conducting sphere which is the atmosphere. As long as the charge which passes away into the atmosphere in a given time is less than the charge received by the earth there must be an accumulation of electricity on the surface which increases the field and so the current. After a certain time the accumulated charge on the earth has risen until it has set up, in the atmosphere, a field sufficiently great to carry away the charge as rapidly as it is received. This is a final steady state which continues so long as the earth receives its constant supply of electricity. When this state has been reached throughout there must be equal quantities of electricity passing upward in all parts of the atmosphere. If the conductivity of the air were the same throughout the atmosphere it would need the same force to drive the same current through all layers. But the air does not have the same conductivity throughout, the conductivity increases with height and therefore the force necessary to drive the current decreases with height; in other words, the potential gradient decreases with height. This adjustment of the force to the conductivity so that a constant current can flow, can only be effected by the accumulation of a volume charge of electricity.

The following is a statement of the process by which the steady state is reached. The charge on the earth itself increases until it produces such a field in the air immediately above the ground that the electricity is conducted from the surface at the rate at which it is received. Now, in another layer some distance above the ground the conductivity is greater, hence if the field due to the charge on the earth extended so high it would produce too large a current through the layer; in other words, the layer would lose electricity faster than it received it from below. The consequence would be that uncompensated positive electricity would appear in the layer. This would counteract some of the field due to the negative charge on the ground and the field in the layer would decrease. Finally the field in the layer owing to the positive charge so induced, would be cut down until a steady state was reached in which the current from the ground would just be conducted through it and no more. This process would go on throughout the atmosphere; in every layer sufficient free positive charge would appear to reduce the field to the value required to conduct the constant current through it.

Thus the two independent variables are, a, the rate at which the earth receives its charge and, b, the conductivity of the atmosphere. Given these the potential gradient and the volume charge adjust themselves until the same quantity of electricity passes through every layer of the atmosphere.

But these are exactly the conditions which we find in the earth's atmosphere; the charge on the earth, the volume charge in the air and the potential gradient are so adjusted that the existing conductivity is just sufficient to carry a constant vertical current through all layers of the atmosphere. We must therefore conclude that the prime cause of the electrical field in the atmosphere is that the earth receives a constant charge of negative electricity which must be conducted away as rapidly as it is received.

We can go further and say that as observations have shown that the same current passes the 6,000-meters layer as leaves the ground, the supply of electricity to the ground can not be obtained from the atmosphere below this height.

We now see why all attempts to solve the problem of the earth's negative charge by considering processes which are completed within the lower atmosphere have led to failure.

To solve our problem then we have to discover some means by which the earth may receive a constant supply of negative electricity without the corresponding positive charge being set free within the earth itself or the lower atmosphere.

This is a much more difficult problem and one which, it may be stated at once, baffles all known physical processes.

When long and serious attempts have been made to solve a problem along recognized lines without result, it appears to me that it is justifiable to draw on one's imagination and to state what kind of process, probable or not, would satisfy the conditions. I therefore propose to describe two processes which would explain the phenom-

[20] Gerdien in Nachr. d. k. Gesellsch. d. Wissens. zu Göttingen, 1905, Heft 5.

enon although both of them are against the recognized principles of physics. My only justification is that these may suggest parallel lines of thought and so be more profitable than a mere statement that we have reached a cul-de-sac.

The *first process* which I can imagine, is that the earth and its atmosphere are constantly being bombarded by particles of negative electricity which have such a great penetrating power that they can pierce the atmosphere in order to be absorbed in the great mass of the earth itself.

This explanation, simple as it is, can not be accepted by physicists for it necessitates a penetrating power of the charged particles quite impossible according to our present knowledge. How great the penetrating power would have to be can be realized from the fact that the absorbing power of the atmosphere is equivalent to a layer of mercury 30 inches deep. The most penetrating electrical particles of which we have knowledge are the β rays from radioactive substances, and none of these can pass even half an inch of mercury. Still, because we know of no electrical particles which can pierce the atmosphere, it can not be said that they are impossible; they can at least be conceived. The measurements of the ionization within closed vessels described above indicate that there is a radiation in the atmosphere far surpassing in penetrating power that from any known radioactive substance, and although I do not go so far as to suggest that this radiation and the one necessary to supply the earth's negative charge are the same, yet it does indicate that our knowledge of radiation is far from complete.

I am now going to make *another suggestion* which at first sight will appear much more improbable than the last one, but I hope to be able to show that it is not entirely ridiculous.

This is nothing less than the idea that there is a spontaneous production of negative electricity within the mass of the earth.

This is against all our ideas of the nature and the methods of production of electricity. It has become an axiom of physics that no electricity can be produced without the production at the same time of an equivalent amount of electricity of the opposite kind. Hence the constant production of negative electricity alone in the earth seems an impossibility.

But our ideas of the axioms of physics are at present in such a state of flux that it would be difficult to state exactly what they are. Twenty years ago it would have been rank heresy to state that the mass of a body was not constant; now the majority of physicists believe that mass, charged or uncharged with electricity, is a function of velocity. This is based upon the experimentally verified facts that the ratio $\frac{m}{e}$ varies with the velocity of the moving body. As it is generally held that the electric charge can not vary, the variation of the ratio has been ascribed to the variation of the mass.

Now, in 1911 Prof. More[21] discussed in the Philosophical Magazine the justification for this assumption and came to the conclusion that a much more satisfactory hypothesis is to "consider m to be the mass of a particle of matter in the Newtonian sense, of constant and small value, and e, the electrical charge, to be a force attribute of matter which varies with the velocity of the particle."

[21] More, *in* Phil. mag., London, 1911, 21: 196.

In other words, the ratio $\frac{m}{e}$ does not change because m changes but because e changes.

The difference is fundamental, but which hypothesis is correct, can not be investigated at present in our laboratories. The change in the ratio $\frac{m}{e}$ although it occurs in all velocities only becomes appreciable when the velocity of the particle approaches the velocity of light, but the only particles which can attain this velocity are the electrons from radioactive bodies, and their masses are so small that we can not determine them directly.

What is required to make the determination is to be able to alter the velocity of a large moving mass, then if the change produces electricity, as More sugggests, it might be possible to detect it, for our means of electrical measurement are much more delicate than our means of mass measurement.

Now, the earth is a very large, moving, insulated mass, and apparently it is producing a constant quantity of electricity, hence it does not seem altogether unreasonable to make the suggestion that the velocity of the earth relative to the center of gravity of the universe, is changing and the charge which appears on its surface is the consequence of this change. What values of the rate of production of electricity are possible can not be stated, for as far as I know the change of $\frac{m}{e}$ for a neutral molecule has not been calculated. The apparent rate of production of electricity by the earth, as judged by the current from the earth into the air, is between 1 and 2 electrons per ton per second. The smallest possible number of electrons associated with a given mass of matter is found from a consideration of the electrochemical equivalent according to which a metric ton of iron (of which we may consider the earth to be composed) has associated with it at least 3.4×10^{28} electrons, hence the change in the number of electrons in a year is only about 10^{-22} of the number present; which shows how small is the quantity of electricity appearing on the earth compared with that associated with the matter of which the earth is composed.

Again I must insist that these two suggestions are not put forward as solutions of our problem; they are only made in order to show along what lines a solution is conceivable, and if they cause one to think they have served their purpose.

4. NATURE AND CAUSE OF BALL LIGHTNING.

During the last few years considerable progress has been made toward solving the problems of the thunderstorm, but many interesting and important questions still remain unanswered. Of these I have only time to refer to one, not probably the most important, but one which to me at least is exceedingly interesting. This is the nature and cause of ball lightning.

From the mass of evidence, which might almost be called chaotic, three characteristics of ball lightning appear to stand out with such prominence that they can not be longer doubted:

(*a*) The body or ball itself, which is able to retain its individuality as it moves through the air, appears to be composed of gas or matter in some novel luminous condition.

(*b*) The balls appear to exist independently of any large electrical intensity, for they have been observed within closed rooms where large electrical fields are impossible, and have also been observed to pass in and out of parallel telegraph wires.

(*c*) They appear to be associated directly or indirectly with large quantities of energy, for they have been observed to explode with violence and have also been seen to fuse the overhead wire of an electric tramway.

There have been, of course, many attempts to explain this phenomenon with an entire want of success. In most explanations the seat of the glow is supposed to be associated with intense electrical force so that the glow itself is of the nature of a brush discharge; this, however, is almost certainly not the case with ball lightning. Until recently we had no knowledge of glowing gas except when associated with an existing electrical discharge or a flame. Prof. Strutt [22] has, however, shown that by means of an electrical discharge a mass of nitrogen can be put into a state in which it continues to glow for some time after it has been removed from the field. I can not help believing that the body of the ball lightning is some gas made to glow in this way by the intense discharge of a lightning flash. Prof. Strutt has pointed out to me serious difficulties of this explanation and I can see others, but future work may remove them. In any case active nitrogen is the nearest physical phenomenon to ball lightning yet produced in our laboratories. I feel that this subject has not received the attention it deserves by experimental physicists, and experiments made to solve this problem might well lead to most important results.

5. NATURE AND ORIGIN OF THE AURORA.

I now come to the last and probably the most interesting of the problems which I propose to discuss.

Many years ago Birkeland [23] suggested that the aurora is due to electrified particles shot off from the sun, and as was only natural, he considered these to be of the same nature as the negative electrons with which we have become so familiar in recent work on cathode rays and radioactive substances. Birkeland suggested that these electrons are discharged by the sun in all directions, but those which pass near to the earth get entangled in the earth's magnetic field and travel along the magnetic lines of force toward the magnetic poles where they produce the effects of the aurora when they strike the upper regions of the atmosphere. This theory was supported by remarkable laboratory experiments and by elaborate mathematical computations made by Störmer.[24]

It was realized throughout that both the experiments and computations left open the question of the sign of the charged particles, but the negative electrons were considered to be the most likely for many reasons, not the least being that glowing gases such as exist at the surface of the sun are known to emit a copious stream of negative electrons.

In 1912, however, Vegard [25] pointed out that, judging from the character of the aurora rays, it is more likely that the aurora is produced by the impact of the charged positive particles corresponding with the α rays of radioactive substances, and it must be admitted that he made out a very strong case.

During the last few years Prof. Carl Störmer has worked out with great patience and success a method of determining the exact height and position in space of the aurora rays. His method consists in photographing the aurora simultaneously from two stations at a considerable distance apart, which in practice is 27.5 kilometers. Then by comparing the apparent position of any marked feature of the aurora relative to the stars on the two plates he is able to calculate the coordinates of that part of the aurora. He has recently published a preliminary report [26] which is of surprising interest. He shows how the aurora rays end very suddenly between 90 and 100 kilometers above the earth's surface, but the result which is of the most interest is that in one marked case he has been able to determine the sign of the electricity in the rays. By calculating the exact position of the aurora ray at a certain time and comparing this with the simultaneous magnetic disturbance at the earth's surface he found that the ray must consist of positive electrons. It must be stated, however, that Störmer has so far only worked out one case, and he himself asks that the result should be taken as provisional until he has worked out further examples.

At the same time, as this observation fits in so well with the considerations advanced by Vegard, I think we are justified in considering the consequences of this remarkable result.

Vegard shows that the α rays which cause the aurora have the characteristics of the rays emitted by radioactive bodies, and his arguments point strongly to their origin being actually radioactive substances in the sun. It is a fascinating occupation to consider what may be the harvest of this discovery if future work should confirm it, and I can not refrain from mentioning some of the thoughts to which it already gives rise.

In the first place, if the sun contains radioactive matter to such a large extent as to give the copious radiation necessary to produce the aurora so far away as the earth, all theories as to the nature of the sun and the supply of his energy must be affected.

What must be the electrical field in the region surrounding the sun due to the constant loss of so much electricity? And what becomes of the matter and electricity distributed in this way to regions far beyond the earth's orbit?

Then, again, as the α radiation from different radioactive substances has different characteristics it may be possible to determine from the nature of the aurora what are the radioactive substances actually present in the sun.

If the α radiation from the sun produces the aurora, what becomes of the β and γ radiations which the same radioactive substances must emit? These may be the cause of the high ionization of the upper atmosphere which wireless telegraphy and Schuster's theory of the daily variation of the earth's magnetic field have led us to expect.

The depth to which the radiation penetrates into our atmosphere may give us information as to the density, and therefore temperature, of the upper atmosphere in regions far higher than we can possibly reach from the earth's surface.

These are only a few of the vistas opened up by this great discovery, and each one of you can doubtless suggest others. It is obvious in any case that another great field of cosmical discovery has opened up, but unfortunately it is one in which we in India are unable to participate. We can at least wish our confréres in polar regions all success in their work.

[22] Strutt, Bakerian Lecture *in* Proc. Roy. soc., 1911, 85A: 219, and in numerous subsequent papers in the Proceedings of the Royal Society.
[23] Birkeland *in* Expedition Norvegienne de 1899-1900.
[24] Störmer *in* Christiania Videnskabsselskods Skr., mat.-nat. Kl. N:o 3, 1904.
[25] Vegard *in* Phil. mag., London, 1912, 23: 211.
[26] Störmer *in* Terr. magnet. and atmosph. electricity, 1915, 20: 1.

RAINFALL DATA OF BERKELEY, CAL.[1]

By WILLIAM GARDNER REED.

[Author's abstract, Washington, D. C., Mar. 10, 1916.]

Engineers are of necessity paying more and more attention to rainfall data, particularly to data of heavy falls of rain in short intervals of time, because of the importance of a knowledge of such heavy falls in connection with the designing of storm sewers and other structures which must carry off the rain water. The records kept by the University of California as a cooperative station of the Weather Bureau since 1886, and by the sanitary engineer and the department of civil engineering of the university since 1910, have been tabulated and studied. These data are the only records available for the east shore of San Francisco Bay, and the study is of interest because it modifies and extends the previous work.[2]

Measurements of precipitation, using a standard 8-inch raingage, have been made at least once each day since October, 1886. Until 1892 measurements were made regularly at 2 p. m. (Pacific time); since 1892 the measurements have been made at 8 a. m. and 8 p. m. Measurements have frequently been made at the end of the rain and during rain, although the practice has varied from time to time. Since 1910 records from a Friez tipping-bucket gage, electrically recording, are available; but these records are more or less fragmentary because of gage failure. The exposures of the gages are shown by Table 1.

TABLE 1.—*Raingage exposures at Berkeley, Cal.*[3]

8-inch raingage.

Date.	Description of exposure.	H.	h.	Read at—
		Ft.	*Ft.*	*Pac. St. T.*
October, 1886, to September, 1892.	Framework over a portion of the observatory building.	347	21	2 p. m.
September, 1892, to September, 1899.	On the ground north of observatory building.	320	1	8 a. m. 8 p. m.
Since September, 1899..	Roof of extension of observatory building.	334	15	8 a. m. 8 p. m.

12-inch tipping-bucket gage.

Since January, 1911.....	Roof of 6 feet × 12 feet shed 12 feet above roof of civil engineering building, 60 feet square.	410	70	Electrically recording each 0.01 inch rain.

Although roof exposure is not to be recommended, conditions at Berkeley have made such exposure necessary and this exposure is fairly satisfactory.[4] A careful examination of the rainfall record of the Students' Observatory shows no break in continuity when the position of the gage was changed in 1892 and in 1899.

TABLE 2.—*Summary of rainfall data, Berkeley, Cal., July, 1887–June, 1915.*

[Compiled from observations by the University of California in cooperation with the U. S. Weather Bureau.]

Month.	Total precipitation.					Number of days with 0.01″ or more.				
		Greatest.		Least.			Greatest.		Least.	
	Average.	Amount.	Year.	Amount.	Year.	Average.	Number.	Year.	Number.	Year.
	In.	*In.*		*In.*		*Days.*	*Days.*		*Days.*	
January.....	6.02	15.99	1911	0.78	1889	12	25	1909	4	1889
February.....	4.16	10.68	1891	0.22	1899	9	25	1915	1	1898
March.....	4.59	13.19	1899	0.31	1898	10	18	1904 1907	3	1898 1901 1914
April.....	1.43	6.72	1896	0.02	1909	6	14	1896	1	1898 1909
May.....	1.27	3.43	1905	0	1909	5	14	1915	0	1909
June.....	0.21	1.24	1907	0	8 yrs.	1	5	1888	0	12 yrs.
July.....	0.02	0.44	1891	0	18 yrs.	0	2	1891 1913	0	24 yrs.
August.....	0.04	0.90	1896	0	14 yrs.	0	2	1896 1898 1906	0	20 yrs.
September....	0.5.8	4.44	1904	0	6 yrs.	2	6	1891 1901	0	8 yrs.
October.....	1.43	5.80	1889	0	1887 1890	4	12	1889	0	4 yrs.
November....	2.68	5.89	1903	0	1890	7	17	1913	1	1890 1894 1907
December....	4.29	12.63	1894	1.22	1898	10	24	1889	3	1910
Year (July-June).....	26.72	46.00	1889–90	14.40	1897–98	66	104	1889–90	52	1897–98

TABLE 3.—*Maximum precipitation in 1 day for each rainfall year, July, 1887–June, 1915, Berkeley, Cal.*

[Compiled from observations by the University of California in cooperation with the U. S. Weather Bureau.]

Rainfall year.	Amount.	Month.	Rainfall year.	Amount.	Month.
	Inches.			*Inches.*	
1887–88.....	1.94	January.	1901–02.....	1.79	February.
1888–89.....	3.43	March.	1902–03.....	2.01	November
1889–90.....	3.63	January.	1903–04.....	*4.75	February.
1890–91.....	4.16	February.	1904–05.....	2.75	September.
1891–92.....	1.56	December.	1905–06.....	1.78	March.
1892–93.....	2.96	December.	1906–07.....	2.31	March.
1893–94.....	3.70	January.	1907–08.....	1.85	January.
1894–95.....	2.20	January.	1908–09.....	2.34	January.
1895–96.....	2.48	April.	1909–10.....	1.66	December.
1896–97.....	2.21	November.	1910–11.....	2.88	January.
1897–98.....	2.19	December.	1911–12.....	1.20	March.
1898–99.....	3.20	March.	1912–13.....	2.39	November.
1899–00.....	3.22	October.	1913–14.....	2.28	January.
1900–01.....	2.06	April.	1914–15.....	1.72	December.

*This amount fell between 1 p. m. Feb. 11, 1904, and 3:45 p. m. Feb. 12, 1904; the 24-hour amount is not available.

TABLE 4.—*Maximum precipitation in 1 day for each month, Berkeley, Cal.*

[Based on records July, 1887–June, 1915, compiled from observations by the University of California in cooperation with the U. S. Weather Bureau.]

Month.	Amount.	Year.	Month.	Amount.	Year.
	Inches.			*Inches.*	
January.....	3.70	1894	July.....	0.44	1891
February.....	*4.75	1904	August.....	0.84	1896
March.....	3.43	1889	September.....	2.75	1904
April.....	2.48	1896	October.....	3.22	1899
May.....	2.16	1905	November.....	2.47	1903
June.....	0.62	1894	December.....	2.96	1892

* Maximum in any one day, 4.75 inches February, 1904.

[1] A revised summary by the author of the material contained in the following papers: Rainfall data of Berkeley, Cal. Univ. Cal. publ. in engin., 1: 69–81. Berkeley, 1915. Rainfall data of Berkeley, Cal., II. Univ. Cal. publ. in engin., 1: 83–116. Berkeley, 1916.

[2] The principal papers dealing with heavy falls of rain for the region are as follows: *Grunsky, C. E.* The sewer system of San Francisco, and a solution of the storm-water flow problem. Trans., Am. soc. c. e., New York, 1909, 65: 294–422.

Hyde, C. G. Report on Richmond, Cal., sewers, 1910.

Le Conte, L. J. Intensity of rainfall at San Francisco, Cal. Trans., Am. soc. c. e., New York, 1905, 54: 197–198, in discussion of *C. W. Sherman*, Maximum rates of rainfall at Boston.

McAdie, A. G. The rainfall of California. Univ. Cal. publ. geog., Berkeley, 1914, 1: 127–240.

McAdie, A. G. The climate of San Francisco, Cal. Washington, 1913. 8°. (U. S. Weather Bureau. Bul. 44.)

[3] The exposures are discussed at length in "Rainfall of Berkeley, Cal.," Univ. Cal. publ. geog. Berkeley, 1913, 1:63–79. Report of the meteorological station, 1912–13. *ibid.*, Berkeley, 1914, 1:247–306. Report, 1913–14. *ibid.*, Berkeley, 1916, 1:373–439.

[4] *Marvin, C. F.* The measurement of precipitation. U. S. Weather Bur. Instrument Div. Circular "E," 3d edition, p. 15. Washington, 1913.

TABLE 5.—*Precipitation of 2.50 inches or more in 24 hours at Berkeley, Cal., July, 1887–June, 1915.*

[Compiled from observations by the University of California in cooperation with the U. S. Weather Bureau.]

Month.	Year.	Amount.
		Inches.
September	1904	2.75
October	1899	3.22
November	.....	None.
December	1892	2.96
January	1890	3.63
Do.	1894	3.70
Do.	1911	2.88
February	1891	4.16
Do.	1904	4.75
March	1889	3.43
Do.	1899	3.20
Do.	1904	2.91

From a statistical and graphic study of all 12-hour periods for which records of intensity are available from the recording gage, the following have been deduced:

(*a*) When 0.80 inch falls in 12 hours, there is a chance that the maximum intensity for 1 hour exceeds 0.50 inch.

(*b*) When 0.80 inch falls in 12 hours, it is probable that 0.30 inch for 1 hour has been exceeded; this is half the maximum shown by the Grunsky curve for San Francisco. (See fig. 1.)

(*c*) When 0.80 inch falls in 12 hours, there is a chance that 0.15 inch in 5 minutes has been exceeded; this is the maximum shown by the Grunsky curve.

(*d*) When 0.80 inch falls in 12 hours, it is probable that 0.07 inch in 5 minutes has been exceeded; this is the lower limit of practical importance; it is half the maximum shown by the Grunsky curve.

TABLE 6.—*Precipitation of marked intensity at Berkeley, Cal., Jan. 1, 1911, to Apr. 30, 1915.*

12-hour period ending at—	Total rain in 12 hours.			5-minute period.		1-hour period.
	Obs.*	C. E.*	Ratio C. E.÷Obs.	Maximum total rain.	Corresponding intensity.	Maximum total rain and intensity.
1911.	*In.*	*In.*		*In.*	*In. per hr.*	*In. per hr.*
Jan. 12, 8 a. m.	0.98	.....	.....	.....	.....	.....
Jan. 13, 8 p. m.	0.88	0.86	0.98	0.13	1.56	*0.15*
Jan. 14, 8 a. m.	2.00	1.96	0.98	*0.06*	*0.72*	0.39
Jan. 20, 8 a. m.	1.76	1.69	0.96	*0.05*	*0.60*	0.35
Jan. 24, 8 a. m.	1.42	1.43	1.01	*0.05*	*0.60*	0.30
Jan. 24, 8 p. m.	0.82	*0.74*	0.90	*0.04*	*0.48*	0.36
Jan. 28, 8 a. m.	1.27	1.18	0.93	*0.05*	*0.60*	0.33
Jan. 29, 8 a. m.	1.03	0.91	0.88	*0.05*	*0.60*	*0.19*
Jan. 30, 8 a. m.	*0.78*	*0.65*	0.83	0.09	1.08	0.32
Mar. 5, 8 a. m.	*0.65*	*0.57*	0.88	0.09	1.08	*0.23*
Mar. 6, 8 p. m.	1.13	.....	.....	*0.06*	*0.72*	0.46
Mar. 7, 8 a. m.	1.14	1.23	1.08	0.29	3.48	0.51
Apr. 5, 8 a. m.	1.45 in 24 hrs.					
1912.						
Jan. 26, 8 a. m.	*0.77*	*0.73*	0.95	0.10	1.20	0.38
Mar. 12, 8 a. m.	1.02	0.96	0.94	*0.04*	*0.48*	*0.26*
Apr. 10, 8 p. m.	*0.45*	*0.41*	0.91	0.09	1.08	*0.18*
May 22, 8 p. m.	*0.12*	*0.08*	0.67	0.08	0.96	*0.08*
Nov. 6, 8 a. m.	1.44	1.25	0.88	*0.03*	*0.36*	*0.19*
Nov. 6, 8 p. m.	0.95	0.85	0.87	*0.04*	*0.48*	*0.21*
Dec. 14, 8 p. m.	*0.50*	*0.49*	0.98	0.10	1.20	*0.26*
1913.						
Jan. 8, 8 p. m.	*0.58*	*0.55*	0.95	0.08	0.93	0.30
Jan. 16, 8 p. m.	*0.41*	*0.35*	0.85	0.08	0.96	*0.23*
Mar. 17, 8 p. m.	*0.62*	*0.49*	0.94	0.09	1.08	*0.20*
Nov. 18, 8 p. m.	0.89	*0.78*	0.88	*0.05*	*0.60*	0.33
Nov. 20, 8 a. m.	*0.59*	*0.57*	0.97	0.08	0.96	0.35
Nov. 27, 8 a. m.	1.00	.....	.....	.....	.....	.....
Dec. 22, 8 a. m.	0.82	.....	.....	.....	.....	.....
Dec. 30, 8 p. m.	1.54	.....	.....	*0.06*	*0.72*	0.33
Dec. 31, 8 p. m.	1.14	0.85	0.75	0.07	0.84	*0.27*

* Obs.—8-inch gage at Students' Observatory.
C. E.—12-inch gage, electrically recording, at Civil Engineering Building.

TABLE 6.—*Precipitation of marked intensity at Berkeley, Cal., Jan. 1, 1911, to Apr. 30, 1915*—Continued.

12-hour period ending at—	Total rain in 12 hours.			5-minute period.		1-hour period.
	Obs.*	C. E.*	Ratio C. E.÷Obs.	Maximum total rain.	Corresponding intensity.	Maximum total rain and intensity.
1914.	*In.*	*In.*		*In.*	*In per hr.*	*In per hr.*
Jan. 2, 8 a. m.	0.99	.....	.....	.....	.....	.....
Jan. 12, 8 p. m.	2.01	2.08	1.04	0.08	0.96	0.52
Jan. 14, 8 a. m.	*0.72*	*0.61*	0.65	*0.05*	*0.60*	0.31
Jan. 17, 8 a. m.	1.02	.....	.....	.....	.....	.....
Jan. 17, 8 p. m.	*0.57*	.....	.....	0.07	0.84	*0.21*
Jan. 22, 8 a. m.	1.16	1.05	0.90	*0.05*	*0.48*	*0.28*
Jan. 24, 8 a. m.	1.32	1.05	0.80	*0.03*	*0.36*	*0.27*
Feb. 20, 8 p. m.	1.15	1.06	0.92	*0.05*	*0.60*	*0.22*
Mar. 29, 8 a. m.	0.82	0.90	1.10	0.10	1.20	0.44
Apr. 4, 8 a. m.	*0.42*	*0.39*	0.93	*0.06*	*0.72*	0.32
Dec. 2, 8 p. m.	*0.71*	*0.69*	0.97	*0.06*	*0.72*	0.33
Dec. 6, 8 p. m.	*0.25*	*0.25*	1.00	0.10	1.20	*0.22*
Dec. 16, 8 p. m.	1.40	1.20	0.86	*0.05*	*0.60*	0.43
1915.						
Jan. 6, 8 a. m.	*0.65*	*0.56*	0.86	0.09	1.08	*0.26*
Jan. 8, 8 a. m.	0.87	0.82	0.94	0.13	1.56	0.52
Jan. 11, 8 p. m.	*0.41*	*0.43*	1.05	*0.03*	*0.36*	0.30
Feb. 2, 8 a. m.	0.83	*0.74*	0.89	0.07	0.84	*0.21*
Feb. 7, 8 p. m.	1.06	0.96	0.91	*0.05*	*0.60*	0.31
Feb. 16, 8 p. m.	*0.62*	*0.51*	0.82	0.17	2.04	0.31
Feb. 22, 8 p. m.	0.99	.....	.....	.....	.....	.....
Feb. 24, 8 a. m.	*0.34*	*0.32*	0.94	0.08	0.96	*0.24*
Apr. 26, 8 a. m.	*0.33*	*0.34*	1.03	0.10	1.20	0.33

Table 6 is a summary of the data of heavy rainfall from which the study was made to determine the occurrence of precipitation of marked intensity. It includes all 12-hour periods from January 1, 1911, to April 30, 1915, during which the amount indicated important intensities. Interesting intensities for Berkeley are:

0.80 inch in 12 hours.
0.30 inch in 1 hour.
0.07 inch in 5 minutes.

The table indicates that the 5-minute or 1-hour periods with precipitation of approximately half the maximum intensity will occur at Berkeley about as often as the 12-hour amount equals or exceeds 0.80 inch.

A study of the records of heavy continuous downpours has made it possible to estimate with a moderate degree of accuracy the probabilities of the maximum intensity when we know the total fall of rain and the duration of the downpour. The results are given in Table 7.

TABLE 7.—*Ratio of average intensity to maximum intensity for short periods of heavy continuous downpour, Berkeley, Cal., January, 1911, to February, 1915.*

	Continuous downpour.			Maximum intensity.		Ratio: maximum÷average intensity.	
	Total rain.	Duration.	Average intensity.	5 minutes.	10 minutes.	5 minutes.	10 minutes.
Average of all downpours...	*Inches.* 0.56	*Min.* 139	*In./hr.* 0.25	*In./hr.* 1.00	*In./hr.* 0.73	4.00	2.92
Maximum	[1] 2.08	[1] 360	[2] 0.51	[3] 3.48	[3] 1.92	[3] 8.50	[3] 4.68

[1] Jan. 12, 1914. [2] Jan. 26, 1912. [3] Mar. 7, 1911.

In the consideration of the run-off of rainfall of marked intensity, the condition of the ground at the time of maximum intensity is important. At Berkeley frozen ground does not affect the problem, but the amount and duration of rainfall immediately preceding the maximum

intensity are of considerable importance.[5] These data are presented in Tables 8, 9, 10, and 12.

TABLE 8.—*Percentage of cases at Berkeley, Cal., 1911–1915, in which the maximum intensity of rainfall for 5 minutes occurred within a given period from the beginning of continuous heavy rain.*

Maximum intensity for 5 minutes occurred within—	Per cent of cases.
5 minutes from the beginning of heavy rain	29
10 minutes do. do.	40
20 minutes do. do.	52
30 minutes do. do.	61
40 minutes do. do.	63
60 minutes do. do.	66
90 minutes do. do.	77
120 minutes do. do.	86
180 minutes do. do.	91
240 minutes do. do.	95
300 minutes do. do.	97
360 minutes do. do.	98
420 minutes do. do.	99
480 minutes do. do.	100

TABLE 9.—*Percentage of cases at Berkeley, Cal., 1911–1915, in which the maximum intensity of rainfall for 5 minutes was preceded by continuous rain for a given amount.*

Maximum intensity for 5 minutes occurred after a fall of—	Per cent of cases.
1.80 inches or less	100
1.00 inch or less	99
0.60 inch or less	96
0.40 inch or less	93
0.30 inch or less	86
0.20 inch or less	81
0.10 inch or less	60

TABLE 10.—*Percentage of cases at Berkeley, Cal., 1911–1915, in which the maximum intensity of rainfall for 1 hour occurred within a given period from the beginning of the storm.*

Maximum intensity for 1 hour occurred within—	Per cent of cases.
1 hour from the beginning of the storm	20
2 hours do. do.	32
3 hours do. do.	35
4 hours do. do.	38
5 hours do. do.	44
6 hours do. do.	47
12 hours do. do.	58
18 hours do. do.	67
24 hours do. do.	76
30 hours do. do.	82
36 hours do. do.	86
42 hours do. do.	87
48 hours do. do.	89
54 hours do. do.	93
60 hours do. do.	95
72 hours do. do.	98
108 hours do. do.	100

TABLE 11.—*Percentage of cases at Berkeley, Cal., 1911–1915, in which the maximum intensity of rainfall for 1 hour was preceded by a storm of given amount.*

Maximum intensity for 1 hour after a fall of—	Per cent of cases.
3.00 inches or less	100
2.50 do. do.	94
2.00 inches or less	90
1.80 do. do.	88
1.60 do. do.	84
1.40 do. do.	82
1.20 do. do.	77
1.00 inch or less	71
0.90 do. do.	70
0.80 do. do.	66
0.70 do. do.	65
0.60 do. do.	61
0.50 inch or less	55
0.40 do. do.	51
0.30 do. do.	46
0.20 do. do.	34
0.10 do. do.	25

TABLE 12.—*Comparison of intensities of rainfall obtained from various curves for San Francisco and vicinity and observed maximum at Berkeley, Cal.*

Reference No.	Formula.	Intensities in inches per hour for periods of—											
		5 min.	10 min.	15 min.	20 min.	30 min.	45 min.	1 hr.	1½ hrs.	2 hrs.	3 hrs.	4 hrs.	5 hrs.	10 hrs.
1	$i=3.68\div\left[\frac{2t}{t+60}+t^{0.4}\right]$	1.79	1.31	1.10	0.97	0.81	0.68	0.60	0.51	0.45	0.38	0.34	0.32	0.25
2	None	2.16	1.50	1.20	1.02	0.83	0.68	0.60	0.51	0.45	0.38	0.34	0.32	0.25
3	$i=7\div t^{0.5}$	3.14	2.21	1.81	1.57	1.27	1.05	0.91	0.74	0.64	0.52	0.45	0.41	0.28
4	$i=5\div t^{0.5}$	2.24	1.58	1.29	1.12	0.91	0.75	0.65	0.53	0.46	0.37	0.32	0.29	0.20
5	None	2.60	2.00	1.65	1.41	1.12	0.88	0.74	0.60	0.51	.....	.....	.....	.....
6	None	3.48	2.00	1.65	1.41	1.12	0.88	0.74	0.60	0.51	.....	.....	.....	.....
7	$i=5.25\div[t^{0.5}-0.75]$	3.52	2.18	1.68	1.41	1.11	0.88	0.75	0.60	0.52	0.39	0.36	0.32	0.22
8	Automatic record	3.48	2.00	.....	1.41	1.10	.....	0.74	.....	0.43	.....	.....	.....	.....

AUTHORITY.

1. *Grunsky, C. E.*, in Trans., Am. soc. c. e., 1908, **65**, 316. Data from all sources for San Francisco before 1899.
2. *Grunsky, C. E.*, in Trans., Am. soc. c. e., 1908, **65**, 316. Data from U. S. W. B., San Francisco, 1899–1908.
3. *Le Conte, L. J.*, in Trans., Am. soc. c. e., 1905, **54**, 198. Data from Thomas Tennent and U. S. Weather Bureau, San Francisco, 1850–1903.
4. *Metcalf & Eddy*, in American Sewerage Practice, v. 1, 1914, p. 230.
5. *Hyde, C. G.*, in Report on Richmond Sewers, 1910. Data from City Engineer, Oakland, 1906.
6. *White, M. K.*, in "Rainfall data of Berkeley, Cal., II, by W. G. Reed and M. K. White." Univ. Cal. publ. engin., Berkeley, 1916, **1**: 83–116. Data from the recording gage at the university, 1911–1915.
7. *White, M. K.*, in Mathematical form of No. 6.
8. Tipping-bucket gage record at Berkeley, 1911–1915.

[5] *Henry, A. J.*, Rainfall of the United States, United States Weather Bureau Bull. D (Washington, 1897), p. 53, also published in Annual Report of the Chief of the Weather Bureau, 1896–97 (Washington, 1897), p. 363.
Correspondence from A. J. Henry in Journ. Western Soc. Engrs., vol. 4 (Chicago, 1899), pp. 165–166, in discussion (pp. 147–194) of *E. Duryea, jr.*, "Tables of excessive precipitations of rain at Chicago, Ill., from 1889 to 1897, inclusive," pp. 73–105.
Metcalf and Eddy, American sewerage practice, vol. 1, p. 268.

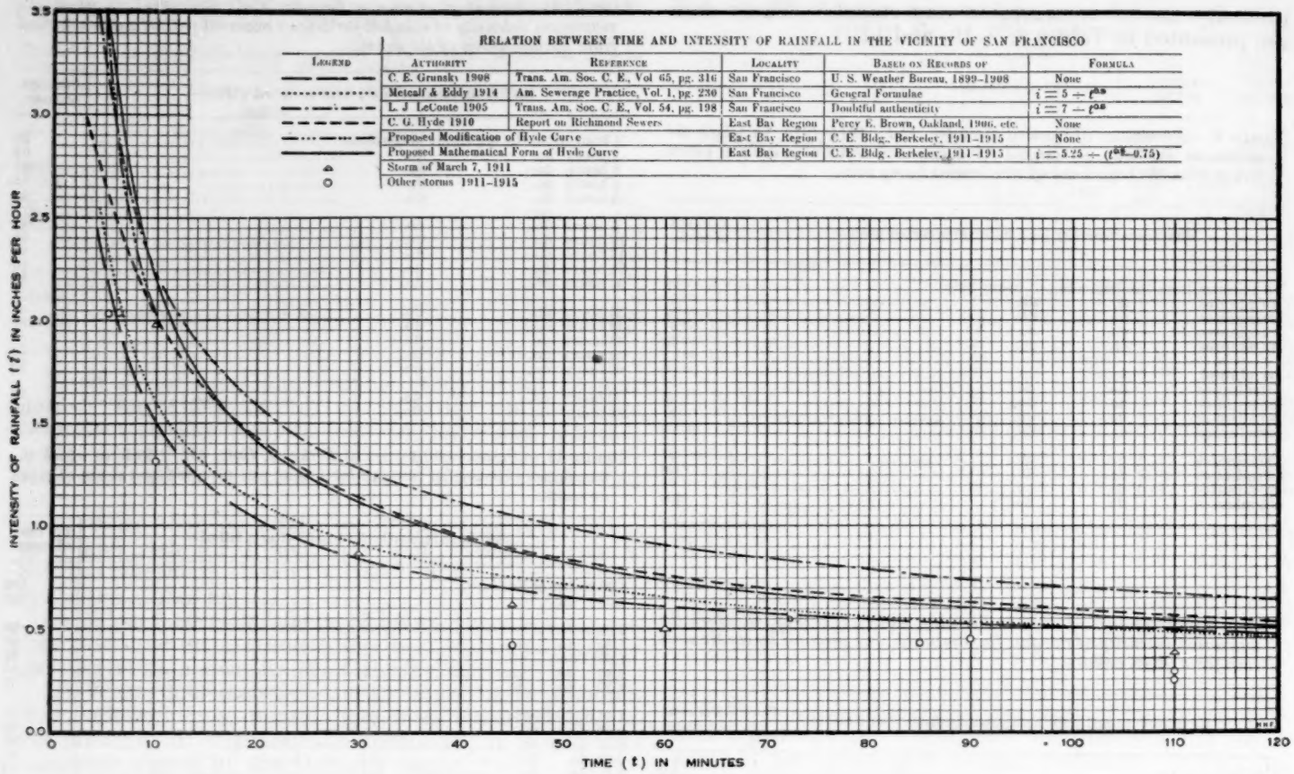
RELATION BETWEEN TIME AND INTENSITY OF RAINFALL IN THE VICINITY OF SAN FRANCISCO
Legend
Authority
Reference
Locality
Based on Records of
Formula
C. E. Grunsky 1908
Trans. Am. Soc. C. E., Vol 65, pg. 316
San Francisco
U. S. Weather Bureau, 1899–1908
None
Metcalf & Eddy 1914
Am. Sewerage Practice, Vol. 1, pg. 230
San Francisco
General Formulae
$i = 5 \div t^{.55}$
L. J. LeConte 1905
Trans. Am. Soc. C. E., Vol. 54, pg. 198
San Francisco
Doubtful authenticity
$i = 7 \div t^{.65}$
C. G. Hyde 1910
Report on Richmond Sewers
East Bay Region
Percy E. Brown, Oakland, 1906, etc.
None
Proposed Modification of Hyde Curve
East Bay Region
C. E. Bldg., Berkeley, 1911–1915
None
Proposed Mathematical Form of Hyde Curve
East Bay Region
C. E. Bldg., Berkeley, 1911–1915
$i = 5.25 \div (t^{.55} - 0.75)$
Storm of March 7, 1911
Other storms 1911–1915
INTENSITY OF RAINFALL (i) IN INCHES PER HOUR
TIME (t) IN MINUTES

Figure 1.

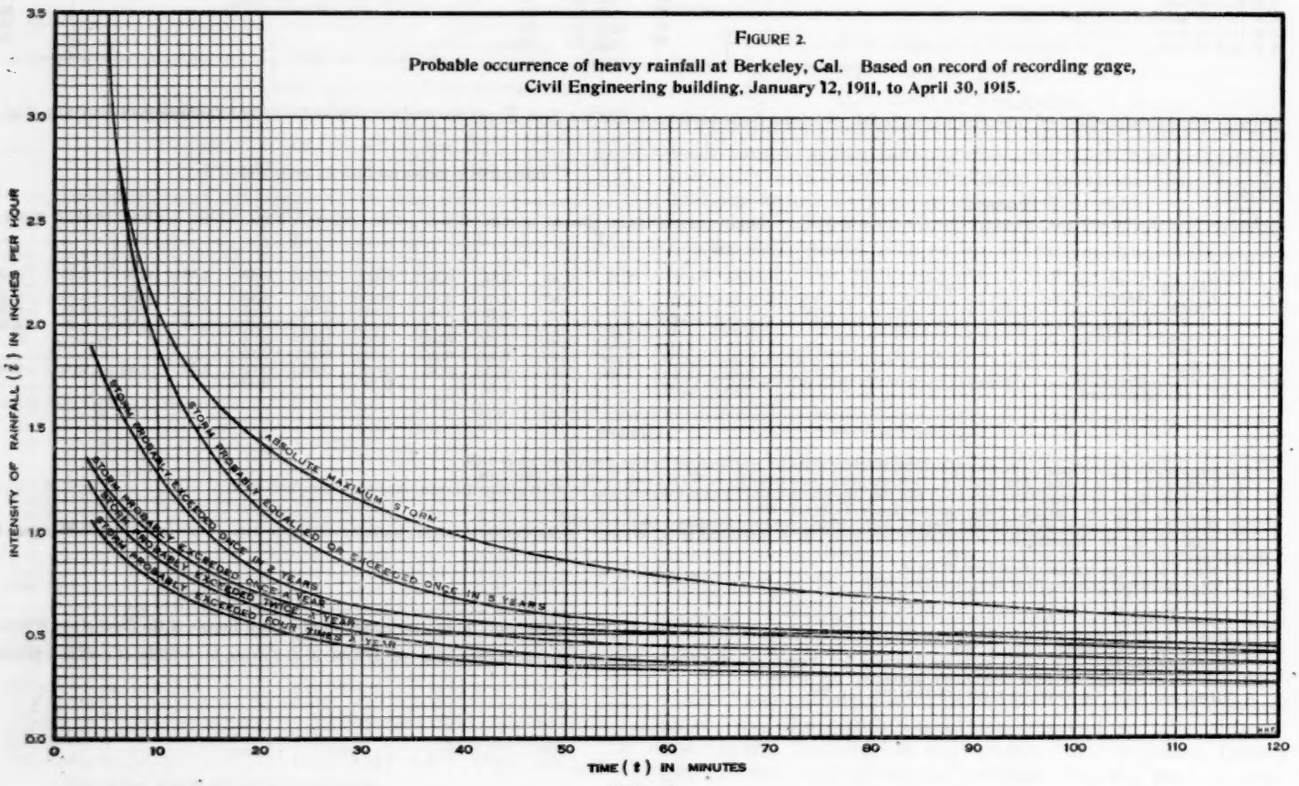
FIGURE 2.
Probable occurrence of heavy rainfall at Berkeley, Cal. Based on record of recording gage, Civil Engineering building, January 12, 1911, to April 30, 1915.
STORM PROBABLY EQUALLED OR EXCEEDED ONCE IN 5 YEARS
ABSOLUTE MAXIMUM STORM
STORM PROBABLY EXCEEDED ONCE IN 2 YEARS
STORM PROBABLY EXCEEDED TWICE A YEAR
STORM PROBABLY EXCEEDED FOUR TIMES A YEAR
INTENSITY OF RAINFALL (i) IN INCHES PER HOUR
TIME (t) IN MINUTES

Figure 2.

Table 12 is a comparison of rainfall intensities, indicated by the various curves which have been used in the design of structures to carry off storm water in the San Francisco Bay region, and also the recorded maximum intensities for the five years during which the tipping-bucket gage has been in operation at Berkeley. The curves are shown by figure 1.

Under some conditions it might be unjustifiable to design a structure for the absolute maximum storm; but if the design is made for a storm of less severity, it is well to know how often the structure is likely to be inadequate. For this reason figure 2 was drawn from the data for all storms in which marked intensities were reached. In order to draw the curves it was necessary to make some interpolations for storms for which the intensity records are incomplete. The curves show within the limits of error imposed by the interpolation and the rather short record (five years) what intensities may be expected in the intervals shown.

DISTRIBUTION OF CYCLONIC PRECIPITATION.[1]

By TORAHIKO TERADA, Rigakuhakushi.

[Dated: Physical Institute of College of Science, Tokyo Imperial University, Nov. 20, 1915.]

[Author's abstract.]

The regional distribution of cyclonic rainfall has already been investigated by many meteorologists.[2] The results, however, differ widely according to the localities concerned, and as yet no general theoretical discussion of the principal moments determining the distribution in question seems to have been attempted.

Recently Messrs. T. Yokota and S. Ôtuki, undergraduates in the Physical Institute of the Science College, undertook the statistical investigation of the problem regarding Japan. The chief data used were the daily weather charts of the Central Meteorological Observatory from January, 1905, to December, 1915. The main islands constituting Japan proper, i. e., Kiushu, Shikoku, Honshu, and Hokushu, were divided into 18 districts, 6 each for the Pacific, the Japan Sea, and the axial region. The percentage expectation of precipitation for each of these districts was calculated for different possible positions of the center of a cyclone. The chief results obtained may be summed up as follows:

(1) In front, i. e., on the northeast side of a cyclone, the precipitation is generally more frequent on the Pacific side of the land than on the Japan Sea side. On the rear side of the barometric depression the reverse is the case. The difference is most pronounced in regions remote from the center.

(2) When the center of the depression lies over the Japan Sea far from the land, specially if near the center of curvature of the axial line of Honshu, the lines of equal rainfall expectation have a tendency to run parallel to the axial line. In this case the draining influence of the coastal mountain ranges becomes obvious, in giving birth to a comparatively rainless zone in the axial region of Honshu.

For the case of the center lying over the Pacific, the rainfall is rather concentrated on a limited region of more or less closed shape.

(3) Comparing the depressions lying over the sea but not very far from the coast, the Pacific depression is associated with a more dense and extended precipitation area on the land than the Japan Sea one.

(4) When the depression lies east of Sakhalin the entire Japan Sea coast is affected, and the lines of equal expectation run parallel to the land.

In connection with these investigations a general theoretical discussion of the problem was attempted. It seems convenient to analyze the secondary influences causing the unsymmetrical distribution of cyclonic precipitation into the following three principal moments:

(*a*) Planetary thermal influence, which consists in the change of temperature with latitude. This influence results in shifting the center of rainfall on the southeastern side of the center of depression, in the Northern Hemisphere, provided the other conditions are uniform.

(*b*) Geographical thermal influence, which consists in the thermal contrast between land and water. The results differ widely according to the season, and also according to the humidity of the land in question. For example, in summer in the Northern Hemisphere, provided the land is sufficiently humid, this effect *taken alone* will tend to increase the precipitation on that side of the depression which looked at from the center has the land on the right-hand side.

(*c*) Hydrodynamical topographical influence, which consists in the forced ascending air current brought about by the discontinuity of the horizontal flux of air at the boundary of two regions with different coefficients of friction.[3] According to this influence, the precipitation will be generally abundant, cæteris paribus, on that part of the coast line, or that side of a mountain range, which viewed from the center of a cyclone has the sea or lowlands on the right-hand side. The direction of the greatest rainfall depends on the difference of friction. These relations have been fully discussed in the paper above cited.[3]

These three influences combined properly seem to explain the peculiarities of rainfall distribution in most diverse cases. For example, result (1) above mentioned is the direct outcome of the third influence (*c*). The result (2) may be explained if we consider that the amount of the third influence (*c*) mainly depends on the angle made by the coast line with the radius vector drawn from the center of the cyclone toward the point concerned. Besides, the draining effect of the mountain range may also be interpreted in terms of the same influence, since on the lee side of the range a downward velocity is superposed on the general upward velocity of air proper to the inner region of a cyclone.

Again, result (3) may be elucidated by the combination of influences (*a*) and (*c*), since in our case the supply of the moisture precipitated is mostly from the sea (the

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[1] *Terada, Torahiko.* On the distribution of the cyclonic precipitations. (An abstract.) [Read Nov. 20, 1915.] Proc., Tôkyô math.-phys. soc., 1915 (2), **8**, no. 12, pp. 382–384. Also separately printed.

[The spelling of place names conforms to the decisions of the U. S. Board on Geographic Names.—C. A. jr.]

[2] *Hildebrandsson, H.* Sur la distribution des éléments météorologiques autour des minimas et des maximas barométriques. Uppsala. 1883.
Van Bebber in Meteorol. Ztschr., 1884.
Åkerblom, Ph. Sur las distribution à Vienne et à Torshavn des éléments, etc.
Krankenhagen in Meteorol. Ztschr., 1885.
Polis in Meteorol. Ztschr., 1904.
Drapczynsky in Meteorol. Ztschr., 1903.
Mill, H. R., in Symons's met. mag., 1904, **39**; Quart. jour., Roy. met. soc., 1908, **36**.
Udden, J. A., in Symons's met. mag., 1906, **41**.
Reed, Wm. G., in MONTHLY WEATHER REVIEW, Oct., 1911, **39**: 1609–16.
Hann, J. Lehrbuch der Meteorologie. 3. Aufl., 1915. p. 524, 552.

[3] In the sense of the generalized Guldberg & Mohn theory. See *T. Terada*, in Proc. Tôkyô math.-phys. Soc., 1914, **7**.

third influence) and the temperature of the landward wind is generally lower on the Japan Sea side than on the Pacific (the first influence).

Finally, result (4) may also be explained mainly by influence (*c*) if we take account of the stationary character of the Sakhalin depressions and the great extent of the area standing under its influence. As for the second influence (*b*), it would have been conspicuous if the seasonal difference of the precipitation were studied. Moreover, many interesting cases investigated by the earlier authorities seem capable of explanation from the above point of view.

The full details of the above investigations, together with a hint for the mathematical treatment of the problem, is published in the Journal of the College of Science, Tôkyô Imperial University, volume 37, article 4.

NOTES.

The Royal Hungarian Imperial Institute for Meteorology and Terrestrial Magnetism announces the sudden death of its former director, Ministerialrath Dr. Nikolaus Thege, Edeler von Konkoly, on February 17, 1916, in the seventy-fourth year of his age.

Dr. von Konkoly was the founder of the astrophysical observatory which now bears his name at Ógyalla, Hungary. In 1890 he was appointed director of the Hungarian Imperial Institute for Meteorology, and during his 20 years of service in that institution performed a great and permanent service in perfecting its organization. He was an honorary member of the Hungarian Academy of Sciences, a member of many scientific societies at home and abroad, and the holder of numerous distinguished orders.

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR MARCH, 1916.

By H. C. FRANKENFIELD, Professor of Meteorology.

[Dated: U. S. Weather Bureau, Washington, D. C., Apr. 1, 1916.]

GENERAL PRESSURE DISTRIBUTION OVER THE UNITED STATES AND CANADA, INCLUDING THE HAWAIIAN AND ALEUTIAN ISLANDS, ALASKA, AND THE WESTERN PORTION OF THE MIDDLE ATLANTIC OCEAN.

High pressure prevailed quite generally over the Aleutian Islands and northern Alaska during the first half of the month, and moderately low pressure during the second half, as a rule. Over the South Pacific Ocean, as indicated by the observations at Honolulu, the reverse conditions obtained, except during the last week of the month when conditions were nearly normal. Over southern Alaska low pressure predominated with marked depressions on the 5th and 6th and on the 21st and 22d. There were but two brief periods of above-normal pressure, one between the 11th and 14th and the other from the 28th until the close of the month.

Over the North Pacific States there were alternating periods of moderate departures from the normal pressure, each about one week in length, beginning with low pressure during the first week. Over the South Pacific States changes during the month were not of consequence.

From the Plateau Region eastward and southeastward there was a constant series of high and low pressure areas at intervals of about three days, and some of these were of pronounced character and extremely rapid movement, notably the low area that was first noted on the 5th over southern Alaska, reaching the Atlantic coast about three days later, and also the disturbance that first appeared over Alberta on the evening of the 19th, reaching the middle Atlantic coast three days later. The principal high pressure area of the month began with the 14th over Alberta and swept southeastward to the Gulf coast during the succeeding four or five days. Over the western Atlantic Ocean, as indicated by reports from Bermuda and Turks Island, there were rapid alternations of moderately high and moderately low pressure, until the last week of the month when low pressure prevailed continuously.

STORM WARNINGS.

On the morning of March 1 a disturbance of marked character was central over western Oklahoma with an extensive high pressure area and a cold wave to the northward. This disturbance moved southeastward to the mouth of the Rio Grande and thence northeastward by way of Georgia to the North Carolina coast and thence to the Gulf of St. Lawrence, increasing steadily in intensity as it progressed, so that by the morning of March 5 the barometer at Port aux Basque read 28.84 inches. On the morning of the 3d the storm was central off the Carolina coast, but no strong winds had as yet occurred and northwest storm warnings were ordered from Jacksonville to New York, and northeast warnings on the New England coast eastward as far as Cape Cod. Small-craft warnings were also ordered on the Florida coast as far as Fort Pierce. As the storm reached the Virginia coast, it was attended by snows that extended northward into New England and strong northerly gales prevailed during the afternoon and night of the 3d from Jacksonville to Eastport, and also on the 4th from North Carolina northward. On the morning of the 4th a disturbance from the Pacific was central over British Columbia. It moved rapidly southeastward with steadily increasing intensity, and on the morning of the 6th was central over Iowa with moderately high pressure to the eastward. Special observations indicated a further increase in intensity and at 5 p. m. southeast storm warnings were ordered from Delaware Breakwater to Portland, Me. During the following night strong winds occurred on the New England coast and on the morning of the 7th, when the storm was central over Georgian Bay, southeast warnings were also ordered for the balance of the Maine coast, and strong winds occurred as forecast. During the 7th the disturbance divided, with one center over southern Virginia and another over southern Lake Huron. In view of the probable development of the Virginia section, northeast storm warnings were ordered at 10 a. m. of the 8th from Sandy Hook to Boston, and at 11 a. m. northwest warnings southward to Savannah, Ga. At 2:30 p. m. the northeast warnings were extended along the entire New England coast and during the day and night of the 8th strong gales occurred as indicated, with velocities on the New England coast reaching from 52 to 56 miles an hour with quite heavy snow. Along the south Atlantic coast only moderate gales occurred. On the morning of the 9th, with pressure of 28.92 inches at Eastport, Me., the warnings from Sandy Hook eastward were changed to northwest and fresh to strong westerly gales occurred during the day. At 9 p. m. the warnings were lowered.

In the meantime another disturbance from the North Pacific appeared over British Columbia on the morning of the 7th, and by the morning of the 10th it had reached the upper St. Lawrence Valley in well-defined formation. At 10:30 a. m. southwest storm warnings were ordered from Delaware Breakwater to Eastport, with instructions to change the same to northwest at sunset. Moderate gales occurred during the afternoon and night of the 10th as far south as Norfolk, Va. Another disturbance from the Northwest quickly followed and passed off the New England coast during the 13th. Only moderately strong winds occurred, except at Nantucket, and no warnings were ordered. Falling pressure during the 12th over Kansas developed a disturbance that, by the morning of the 14th, extended as a trough from northern Texas through the Ohio Valley with three centers of disturbance, the forward one over West Virginia. As the 8 p. m. map showed evidences of further development of the center over West Virginia and the dissolution of those to the southwestward, northeast storm warnings were ordered from Cape Henry, Va., to Eastport, Me., for it was apparent that the storm would continue eastward off the Virginia coast. On the morning of the 15th northwest warnings were ordered south of Cape Henry as far as Jacksonville, and during the day fresh gales occurred along the entire coast from Jacksonville northward. The storm center had turned northeastward after reaching the

Virginia coast, and the warnings, changed to northwest, were continued from Delaware Breakwater northward except at Eastport, Me. The winds did not subside until during the night of the 16th–17th.

During the night of the 19th a disturbance appeared over Alberta and moved southeastward with rapidly increasing intensity, so that by the night of the 21st it was central over western Missouri with a barometer reading of 29.18 inches at Kansas City. As there was quite a strong gradient to the southward, small-craft warnings were ordered displayed on the 22d on the middle coast of the Gulf of Mexico, and fresh to strong south and southwest winds were forecast. These occurred as indicated. On the morning of the 22d the disturbance was central over southern Ohio with a still further increase in intensity. Southeast storm warnings were ordered at 9:25 a. m. from Delaware Breakwater to Eastport, with advices reading that strong gales and snow were expected, with winds shifting to north and northwest with continuing gales and much colder. Southwest warnings were also ordered at the same time southward as far as Jacksonville and strong southwest to west gales were forecast. This proved to be the most severe storm of the month. Strong gales occurred along the entire coast from northern Florida northward, accompanied on the middle Atlantic and New England coasts by quite heavy snowfall. The storm continued rapidly eastward, and on the morning of the 23d was central off the coast of Nova Scotia, with a barometer reading of 28.92 inches. Moderately strong westerly winds were prevailing, but the storm warnings were not renewed.

The rapid succession of the northwestern disturbances continued, and on the night of the 23d another of marked intensity was central over eastern Colorado. On the morning of the 24th there were two centers of disturbance—one over eastern Nebraska and another over western Colorado. Both moved eastward with decreasing intensity, but the southern one was sufficient to cause fresh to strong southerly winds on the east Gulf coast, for which southeast storm warnings were ordered at 10 p. m. of the 24th. This disturbance, in marked contrast to its predecessors, moved very slowly eastward, taking four days to make the journey from the middle Mississippi Valley to the North Carolina coast. On the night of the 27th, when the principal section of the disturbance was central over North Carolina, its further development was more or less uncertain and advisory messages of fresh to strong northeast winds were distributed along the middle Atlantic and southern New England coasts, but storm warnings were not ordered, as it was not thought that they would be necessary. Conditions on the following morning indicated that this view was correct, but small-craft warnings were ordered from Delaware Breakwater to New York and moderately strong winds occurred. On the morning of the 29th the disturbance still persisted off the North Carolina coast with some faint evidences of development to the northeastward and northeast storm warnings were accordingly ordered for Block Island, R. I., and Nantucket, Mass., only. There were some strong winds during the day, but none of consequence, and at 9 p. m. the warnings were lowered.

In addition to these warnings, small-craft warnings were ordered at various times on the Gulf coast for the fresh and moderately strong winds that occurred.

While the northwestern storms were making their rapid progression across the central portion of the country, cautionary advices to open ports on Lake Michigan became necessary at times and such were ordered on the night of the 5th, warning that gales might be expected on the following day; on the morning of the 9th, for strong southwesterly winds; and again on the evening of the 21st for strong northeast to north winds, possibly gales with snow and rain. These advisory warnings were justified in each instance.

COLD WAVES AND FROSTS.

A marked high pressure area with low temperatures followed the storm of the early days of the month, and on the morning of the 3d cold-wave warnings were ordered for North Carolina, South Carolina, Georgia, and the northern and central portions of Florida. These warnings were verified by the occurrences on the 4th of freezing temperatures to the Georgia-Florida line and by heavy frosts in northwest Florida. However, the fall in temperature advanced eastward more rapidly than had been anticipated and the cold wave had already covered the interior of the Southern States on the afternoon of the 3d, following a forecast of colder weather made on the previous day. On the morning of the 4th, with marked high pressure and low temperatures prevailing over the South, frost warnings were issued for Florida as far south as the interior of the southern portion. Heavy to killing frosts occurred on the morning of the 5th as indicated. On the morning of the 8th, with high pressure and low temperatures prevailing over Texas following a disturbance that was passing up the Atlantic coast, frosts were forecast for South Carolina, southwest Georgia, and the east Gulf States, and on the morning of the 9th frost occurred as forecast in South Carolina, Georgia, and Florida, but none was reported from Alabama and Mississippi, although freezing temperatures occurred in portions of the two last-mentioned States. As pressure conditions had not changed materially, warnings were issued on the morning of the 9th for freezing temperature or heavy frost in the Carolinas and for frost in Georgia and the central and northeast portions of Florida, which forecasts were fully verified by the occurrences on the following morning.

On the morning of the 11th a moderate disturbance was moving off the Georgia coast with a cold high area to the northwestward; warnings of frost and freezing temperature were issued for South Carolina, and freezing temperatures were reported on the following morning with heavy frost extending into southern Georgia. These Georgia and Alabama frosts had already been forecast on the morning of the 11th. There was no prospect of any immediate change of conditions over the Southeastern States, and accordingly frost warnings were ordered on the morning of the 12th for the interior of South Carolina, for northern and central Florida, and for Georgia. The frosts occurred on the morning of the 13th as forecast.

At this time the high pressure area from the Canadian Northwest had reached Lake Superior, accompanied by falling temperatures, but as it was thought that there could be no further decided fall in temperature, no warnings were ordered for the cold waves that actually occurred on the morning of the 14th over the eastern and southern portions of upper Michigan, where the temperatures were 0° F. or slightly below. Nor were cold-wave warnings ordered over the Ohio Valley, Tennessee, and the South for the cold wave that occurred on the morning of the 15th, although colder weather had been forecast over practically this entire district. This cold wave was caused by the rapid eastward movement of the low pressure area of the 14th that extended from

Texas to the upper Ohio Valley, and of the strong cold high area to the northwestward. On the night of the 14th, however, warnings of frost or freezing temperature were sent to stations in Alabama and Mississippi, and on the morning of the 15th to Mississippi, Alabama, northern and central Florida. Cold-wave warnings were also ordered for North Carolina and warnings of frost and freezing temperature for the interior of South Carolina, eastern and southern Georgia, and southwestern Virginia, and on the following morning conditions were as had been forecast.

On the morning of the 16th, with cold high pressure still prevailing throughout the West and South, warnings of freezing temperature or lower were sent to North Carolina, South Carolina, Georgia, and northern and central Florida and warnings of frost in central Florida as far down as the twenty-sixth parallel. On the morning of the 17th frost occurred as far south as the northern suburbs of Miami, Fla. As conditions were changing but slowly, frost warnings were repeated on the morning of the 17th for the Carolinas, Georgia, and northern and central Florida, as far south as the twenty-seventh parallel, and again frosts occurred as forecast.

On the morning of the 22d the great storm of the month was central over southern Ohio, with a high area over Manitoba moving southeastward. Accordingly, cold-wave warnings were ordered for Kentucky, Indiana, central and southern lower Michigan, Ohio, West Virginia, and the southern portion of western Pennsylvania, and frost warnings for Tennessee and the northern por, tions of Alabama and Mississippi. These forecasts were verified, except in a few scattered localities where the fall in temperature was not sufficient to technically justify the cold-wave warnings. The minimum temperatures reached were much below the required limit-however. On the morning of the 23d, with moderately high pressure over the Ohio Valley, warnings were issued for freezing temperature in Virginia, heavy frosts in North Carolina, and frosts in South Carolina, northern and central Georgia, and central and eastern Tennessee. These forecasts were not verified, as the rapid approach of a disturbance from the extreme West caused east and southeast winds with increasing cloudiness.

On the morning of the 26th, with a slowly moving disturbance central over Missouri and marked high pressure over the central Rocky Mountain region, frost warnings were ordered for Alabama, Mississippi, western and southern Tennessee, and extreme northwestern Florida, contingent upon the weather clearing. Cold-wave warnings were also ordered for northwestern Ohio, northeastern Indiana, and Michigan. At the time these warnings were made the western disturbance had been progressing at a fair rate and the forecasts were predicated upon the assumption that this rate would be maintained. However, the succeeding 24-hour movement was very slight and, as a consequence, the cold-wave and frost forecasts were failures. On the morning of the 27th frost warnings, predicated upon clearing weather, were again issued for northwestern South Carolina, northern and central Georgia, Alabama, Mississippi, and Tennessee, and on the morning of the 28th frosts occurred as forecast, except in central and eastern Tennessee, where cloudy weather continued.

On the morning of the 28th frosts were forecast for North Carolina, interior South Carolina, northern and western Georgia, the northern portions of Alabama and Mississippi, and for Tennessee. Frosts occurred on the following morning over Tennessee and the east Gulf districts, but failed in the Carolinas and Georgia on account of the slow movement of the low pressure area above referred to. On the 30th, with high pressure prevailing generally east of the Mississippi River, frosts were forecast for southeastern Georgia, northwestern South Carolina, and the interior of North Carolina, and were verified except in Georgia. On the morning of the 31st frost warnings were also issued for southeast Virginia, and on the morning of April 1 light frost was reported.

DISTRICT WARNINGS DURING MARCH.

Chicago District.—During the night of March 8–9, 1916, a disturbance moved rapidly southeastward from Saskatchewan to western Lake Superior, followed by rapidly rising barometer and a marked fall in temperature in the Saskatchewan Valley. Cold-wave warnings were issued on the morning of the 9th for North Dakota and northern Minnesota, and later in the day were extended to cover southern Minnesota, southern Wisconsin, northeastern Iowa, and extreme northern Illinois. No other warnings were issued during the month, except on the morning of the 25th, when cold-wave warnings were ordered for the upper Mississippi and lower Missouri Valleys, a disturbance being centered over Missouri at that time, with increasing pressure attended by lower temperature in the trans-Missouri region.

The only frost warning issued was that for Cairo, Ill., on the 27th.—*Charles L. Mitchell, Assistant Forecaster.*

Denver District.—Cold-wave warnings were issued on the morning of March 2 for southwestern Colorado, northwestern New Mexico and northeastern Arizona, and were fully verified. Cold-wave warnings were again issued on the morning of the 23d for western Utah, and on the evening of that date for eastern Colorado and eastern New Mexico. These were verified except in the vicinity of Pueblo and in southeastern New Mexico. On account of the forward season, warnings of frost and freezing temperatures were necessary earlier than usual. Warnings were issued almost daily for some part of the district after the 22d, and were fully verified except near the close of the month in the vicinity of Salt Lake City and in southeastern New Mexico.—*F. H. Brandenburg, District Forecaster.*

New Orleans District.—On the morning of March 1, a cold-wave warning was issued for Abilene, Tex. Small-craft warnings were ordered for stations on the Texas coast on the 14th, 21st, and 23d. On the 25th a small-craft warning was issued for New Orleans. Frosts occurred on several dates as far south as the berry region, for all of which warnings were issued. On two dates conditions indicated the probable occurrence of frost, and warnings of probable frosts in a portion of the district were issued, but not verified.—*William B. Stockman, Assistant Forecaster.*

Portland, Oreg., District.—Live-stock warnings were issued on March 2 and 4. They were in continuation of the the warning issued on February 28 and extended on the 29th to cover all sections where such warnings were desired. These warnings were well verified. Most of the storm warnings issued were general, and all were verified in whole or part except that of the 19th. The most severe storm occurred on the 21st, an 80-mile southerly gale having been reported from the mouth of the Columbia River.

Of the frost warnings sent out, those on the 17th, 24th, and 25th were not verified. Fruit buds in several localities were far enough advanced to be susceptible to damage from freezing temperatures and several of the warn-

ings sent to the Rogue River Valley were not specially timely or accurate.—*T. Francis Drake, Local Forecaster.*

San Francisco District.—The only important warnings issued during March were those for frosts on the 23d and 24th. Frosts occurred quite generally on the mornings of the 24th and 25th, but moderate winds and some cloudiness prevented any serious injury.—*G. H. Willson, District Forecaster.*

ON PRESSURE-CHANGE CHARTS.

By EDWARD H. BOWIE, District Forecaster.

[Dated: Washington, Nov. 27, 1915.]

An important change in the construction of the pressure-change charts prepared at the central office of the Weather Bureau became effective on August 1, 1915. During many years previous to this date [1] there were entered on these charts the 24- and 12-hour changes and the departure from the normal sea-level pressures for all stations from which both the 8 a. m. and 8 p. m. (seventy-fifth meridian time) observations were received by telegraph from the area comprising the United States and southern Canada. The 12-hour changes were made after the application in each case of a correction for the diurnal fluctuation that made the 8 a. m. comparable with the pressure observed at the previous 8 p. m. observation, and similarly the 8 p. m. with the pressure at the preceding 8 a. m. observation. There was obviously no correction necessary in making the 24-hour changes. The pressure changes having been computed, lines (isallobars) in red were drawn for each 0.10 inch rise and fall in 24 hours and a heavier red line drawn through points of no change. Similarly, blue lines (isallobars) for each 0.10 inch rise and fall were drawn for the 12-hour pressure changes. The revised chart omits the 24-hour changes and the red lines drawn to these changes. On the new chart isobars for sea-level pressures are drawn in red and superposed on these are blue lines (isallobars) drawn through points having equal 12-hour changes, a line being drawn through each 0.10 inch fall or rise and a heavier line for zero change. In addition to these lines, the "barometric tendency" or pressure change in the two hours immediately preceding the time of observation at any station is entered in green figures when telegraphed. The "barometric tendency" is telegraphed from selected stations only when the change in pressure equals or exceeds 0.04 inch in the two hours immediately preceding the observation. Figures 1 and 2 (Chart XLIV–34, 35) show the old form of pressure-change maps, and figures 3 and 4 are reproductions of the revised maps. The "barometric tendency" is indicated by large bold-faced figures in red.

The change was made that the forecaster might see at once the relation between the highs and lows and the pressure changes that have taken place during the time between the current observation and that which immediately preceded it, and it is the consensus of opinion of the forecasters at the central office of the Weather Bureau that the new form of pressure-change chart has many advantages over the one previously in use and is a valuable aid in forecast work.

[1] The preparation of pressure-change charts in the Forecast Division, U. S. Weather Bureau, began in 1872, when observations were telegraphed thrice daily and charts for 8-hour intervals were prepared until June 20, 1888.
Figures E. H. B. 1 to E. H. B. 8 form charts XLIV–34 to 45.

NATURE OF THE PRESSURE CHANGES.

There have been published a number of theories as to the origin and nature of the areas of rise and fall in pressure as shown by the pressure-change maps. Hanzlik in a paper on "Relations between velocities of lows and the areas of rising and falling pressure accompanying them" (MONTHLY WEATHER REVIEW, May, 1906, **34:** 205) writes:

> The results of the investigation on the relation of areas of falling and rising pressure to the lows are given by Sresnewsky:
> (1) The center of the cyclone is always to the left of the point of most rapid fall of pressure. (2) This is explained as due to the greater eccentricity of the outer isobars of the cyclone and also due to the difference of barometric gradients on both sides of cyclones. (3) The area of most rapid decrease in the southeast quadrant of the cyclone coincides with the area of strongest storms and moves nearly parallel to the center of the cyclone. (4) There are cases when the area of fall moves apparently independently of the cyclone while the latter remains nearly stationary in the extreme north of Europe. These are the most important points in Sresnewsky's investigation that concern the relation of cyclones to the areas of fall and rise.
> The atmospheric waves are, in Ekholm's opinion, very important phenomena. When there are strong storms in Swedish waters the areas of fall and rise follow similar tracks parallel to each other, while the cyclone keeps somewhat to the left of the track of the area of fall. When the cyclone reaches the land the intensity of the storm diminishes, the velocity of motion of the storm decreases, and the areas of fall and rise, with some delay, move in a southern or southwestern direction as if there were no apparent connection between them and the cyclonic area. The continued study of these areas of change in their relation to the cyclones led Ekholm to believe that for the weather and wind these are of greater importance than the cyclones themselves. "It seems to me highly probable," says Ekholm,[2] "that these oscillations are caused by the cyclones and anticyclones of higher levels, which sometimes but not always cause a corresponding cyclone or anticyclone on the surface of the earth." Worthy of mention is the cyclonic character of the area of fall, namely, the overcast sky and the occurrence of rain. Ekholm closes his paper with some remarks on the charts of change for other meteorological elements.

Hanzlik expressed a view concerning the areas of rise and fall that is quite different from that of Ekholm. He would bring the moving areas of falling and rising pressure into close connection with both the currents assumed to produce the lows. He associates the northerly winds with the areas of rise and the southerly warm winds with the areas of fall, (1) because the extreme temperature changes lie within the areas of rise and fall, and (2) because these two currents are assumed to be the primary cause which gives rise to the low.

The present writer is of the opinion that these areas of rising and falling pressure are not independent phenomena, although they may seem to be, but that they arise directly from the movements of and changes in pressure in highs and lows, with which they are associated. This, it is believed, is demonstrable and an effort will be made herein to show the truth of this statement.

OBSERVATIONS ON MAXIMUM PRESSURE-CHANGE AREAS.

One hardly needs to demonstrate the truth of the fact that a symmetrical low is, at any given moment, moving toward that point or region within its area where the pressure at the moment of observation is falling most rapidly. This maximum fall within the area of a low lies somewhere along a line passing through the center of the low and in the direction of advance of the low center and normal to the closed concentric isobars. The least change in pressure will be, of course, along two lines parallel to the direction of movement of the low, one on

[2] Ekholm, *in* Meteorol. Ztschr., August, 1904, **21:** 355.

each side of the low center, and tangent to the outer closed isobar.

Assuming that there be moving eastward at a uniform rate of progression on a given map, in the same latitude, a symmetrical low preceded by a symmetrical high; suppose these to be in tandem formation, of equal area and uniform pressure gradients, and that neither undergoes any change in configuration of isobars, in pressure level, nor in the linear distance from the center to center in a given interval of time. Then at the end of the given time interval, the region of maximum pressure fall will be along a straight line extending from the position of the center of the low at the end of the assumed interval to the position of the center of the preceding high at the beginning of the assumed interval. This is shown by the red lines on the chart figure 5, which represents an ideal weather map on which only one low and one high appear. On this chart (XLIV–38) A is the position of the center of the low at the beginning and A_1 the position of the center of the low at the end of the assumed interval; similarly B is the position of the center of the high at the beginning and B_1 the position of the high at the end of the assumed interval of time. The distance AB is the same as that between A_1 and B_1. The changes in pressure are made at each point where an isobar of A or B crosses an isobar of A_1 or B_1, and red lines are drawn for each 0.10-inch fall. It will be found that the maximum change is along a line connecting A_1 and B. Now, if in the example given above, where the distance between the low and the high that precedes it does not change, the pressure rise or fall say 0.20 inch in A and a similar amount in B, then the region of maximum fall will still lie on a line connecting A_1 and B. If, however, the pressure level in A fall 0.20 inch in the assumed time interval during which the low moves to A_1, while the pressure undergoes no change in B, then the maximum fall will be near the center of A_1, as shown by figure 6 (XLIV–39). Should the pressure undergo no change in the high but rise in the low, then the maximum pressure fall will be near the center of the high, B, as shown by figure 7 (XLIV–40). If the pressure level fall in the high, B, while moving to B_1 but does not change in the low, then the maximum fall is also near the position of B, as will be seen by figure 8 (XLIV–41). If the pressure level rise in the high and undergo no change in the low, then the maximum pressure fall is near the center of the low, A_1, as shown by figure 9 (XLIV–42).

In the examples given the distance between the low and the preceding high remained unchanged. If, however, the distance increase or decrease, the maximum pressure fall varies both in amount and position. Thus, in figure 10 (XLIV–43), the high moves faster than the low and the distance between the two at the end of the interval is greater, then the position of the maximum pressure fall is near the center of the high, B. Similarly in figure 11 (XLIV–44), if the low move faster than the high and the distance between the two is less at the end of the interval, the position of the maximum pressure fall is near the center of the low, A_1. The daily pressure-change map will show changes, such as these, that arise from similar movements of and changes in pressure in highs and lows.

Many other examples could be given of how the position of the area of maximum pressure fall varies with the movements of the highs and lows, and some of the results are astonishing. For example, it has been commonly supposed that the area of maximum pressure fall is always in front of and in the line of advance of lows that move rapidly, but it is possible to show that *a low that moves with great speed may have the maximum pressure fall, in the given interval, in its rear. This occurs when the low moves beyond the position occupied by the high at the beginning of the interval, and it is seen occasionally on the weather map.* This is shown by figure 12 (XLIV–45). On this chart the low, A_1, is assumed to have moved from A to beyond the position of the high, B, at the preceding observation, while the high, B, is moving ahead of it. The position of the high, B_1, at the end of the interval is not shown.

Nothing has been said concerning the areas of maximum rise, but it is believed that these can be shown to be dependent, as are the areas of maximum pressure fall, on the changes in intensity, speed, and direction of movement of highs and lows. It follows that the isallobaric charts are but representations of pressure changes that result directly from the movements of and changes of pressure level in highs and lows, and nothing more. It is obvious, however, that the nature of these maximum pressure changes being known, many precepts that will materially aid the forecaster may be found. But it is not the intention of the present writer to consider this phase of the question.

These charts, as stated above, are assumed to represent the ideal types of lows and highs as seen portrayed on the weather maps of the United States with this important difference, that the pressure-gradients here represented as uniform, increase in nature from the high to the low. This natural increase in the pressure-gradient from the high toward the center of the low places the area of maximum presure fall nearer the center of the low and modifies somewhat the configuration of the isallobars. Nevertheless, the rules herein stated hold good in principle for ideal types of highs and lows as shown by weather charts of the United States. The pressure changes resulting from complicated cases of isobars surrounding highs and lows do not make it easy to formulate precepts concerning them. There are, moreover, pressure oscillations, generally small in amount, which take place uniformly and gradually over larger areas and independently of the movement of highs and lows. These oscillations result, in all probability, from changes in the general circulation and are shown first in modifications of the subpermanent areas of high and of low pressure, or the so-called centers of action.

FIRE-WEATHER WARNINGS.

By HENRY E. WILLIAMS, Meteorolgist in charge of Forecast Division.

The following extracts from reports rendered and papers prepared by the district forecasters are published with a view to bringing down to date the available information relating to the fire-weather warning service, as this project is hereafter to be designated. This service was authorized in the Portland and San Francisco forecast districts in the summer of 1913 on the recommendation of District Forecaster E. A. Beals, at the suggestion of officials of the United States Forest Service and the Western Forestry and Conservation Association. Only one or two warnings were issued during 1913, and those for the Portland District. None were issued in the San Francisco District. In 1914 the service was extended to all the other forecast districts, and the reports from these districts show warnings issued as follows:

Fire-weather warnings issued by the several forecast districts during 1913, 1914, and 1915.

Forecast district.	1913	1914	1915
Washington	None.	None.	None.
New Orleans [1]	None.	None.	None.
Denver	None.	None.	1
Chicago	None	6	5
San Francisco [2]	None.	(?)	(?)
Portland, Oreg.	2	17	8

[1] Warnings only on request of district foresters. [2] Record incomplete.

That these warnings were considered valuable by the interests affected is shown by the following resolution adopted by the Forestry Industry Conference, composed of the Western Forestry and Conservation Association and State, Federal, and British Columbia forest agencies, meeting in San Francisco October 19 and 20, 1915:

> The usefulness of the United States Weather Bureau in forecasting dangerous fire weather is no longer open to question. Trial has demonstrated that adequate provision of men and instruments to perfect the system will do much more to prevent fire losses than any other possible expenditure of the small sum needed, say $10,000 annually. No one else can do this work and we appeal to Congress to provide for it. The public values that it will protect are tremendously greater and slower of recovery, if destroyed, than any other which the Weather Bureau now safeguards.

In view of the reasonable success of these warnings during the past three years, a period of informal study and preparation, the Chief of the Weather Bureau feels justified in making the fire-weather warnings service a recognized branch of Weather Bureau activity. Accordingly, formal instructions (Instructions No. 26) were issued on April 10, 1916, wherein—

> District forecasters are authorized to issue warnings, to be known as "fire-weather warnings," of conditions favorable for the inception of fires in the forested regions of their respective districts. * * *

Portland, Oreg., District.[1]—Referring to letter of November 16, 1915, from the Chief of the Forecast Division relative to the number of fire-weather forecasts that have been issued from this district for the seasons of 1914 and 1915, I beg to inclose copies of each, which number 17 in 1914 and 8 in 1915, or 25 in all.

These forecasts, so far as practicable, are made in sets, or, in other words, when hot weather or increasing winds are expected, a forecast is made, and followed each day by another showing such modifications as may be necessary, until a forecast can be made of the termination of the dangerous conditions. By counting the forecasts after the foregoing plan, seven sets were issued in 1914 and three in 1915.

So far as the benefits are concerned I wish to state that I have been informed by the chief wardens of some of the forest fire associations that they were of help to them, and their letters in this connection were promptly forwarded at the time to the central office. Also at the last two conventions of the Western Forestry and Conservation Association, both of which I attended, the sentiment of those present was strongly in favor of continuing this work. At the last convention a resolution was passed calling upon Congress to appropriate the sum of $10,000 to be applied in strengthening the service.—*E. A. Beals.*

San Francisco District.[2]—I regret to report that I am unable to give either the number of times during 1914 and 1915 or the dates on which the Forest Service was advised to expect fire winds, or what is nearly as important, very hot spells of weather, as these greatly add to the activity of a forest fire.

Whenever either of these conditions is expected, the plan has been to call up the district forester by telephone and outline the condition expected and in what portion of the State it will occur. The forester then notifies his supervisors and they issue the necessary instructions and make preparations to meet the condition indicated.

The seasons of both 1914 and 1915 were remarkably free from fire winds or very hot spells of weather. This was especially the case during the past summer.

This work is in its infancy, and our efforts, while in a great measure satisfactory, have been conducted along the broadest lines, because the problem is a new one with many angles and possibilities of which we know but little. What we need is reliable and complete wind data from the forests for study and first-hand field experience. At present our daily weather maps give us the necessary information for a general forecast covering large areas. This is not satisfactory. Our problem is one of great detail and the details must be worked out. The forests are in the mountains where the wind directions and in a great measure the velocities are controlled by the topography of the country, and we can not hope to be in a position to apply the forecasts to specific localities until these are understood.

From our present knowledge of this work, there appear to be two things that should be done at once:

(*a*) Get records of wind velocities and directions from a number of selected ranger lookout stations at different elevations in each forest for study in conjunction with the daily forecast charts.

(*b*) Active and energetic men, one in each forecast district, for field service under the direction of the district forecaster. They should be thoroughly practical, and after carefully studying the methods used by the Forest Service in fighting fires and the effect of different kinds of weather upon the spreading of fires, they should be capable of devising means for closer and more effective cooperation between the Forest Service and the Weather Bureau for the prosecution of this important work.

The diurnal range of temperature in the mountains is considerable, and it is a well-known fact that at night, when the temperature approximates the dew point and the relative humidity is high, forest fires lose much of their energy. But for the same reason, successful backfiring on nights when the humidity is very high is almost impossible owing to the difficulty in getting them to burn. We should be able to advise the district forester when such conditions are probable; then, if his men reach the fire line after the temperature has begun to fall, he can allow them to rest up and be fresh for effective fire fighting the next morning; otherwise they will be tired and worn out by ineffective work during the night and not able to keep up the work at the most critical time.

During the past season we have made an attempt to gather some data of wind velocities in the forests in this district by placing five anemometers at lookout stations across the northern part of the State in the Klamath and Shasta National Forests at Dry Lake, Orleans Mountain, Mount Eddy, Grizzly Peak, and Sisson. (Map showing locations of the above stations forwarded to the central office with letter of July 30, 1915.) Unfortunately we were not able to equip them with self-registers, and therefore much valuable detailed data will not be available for study. However, the rangers were instructed to make dial readings and note the direction of the wind every three hours during daylight. They were also instructed in case the wind changed to a northerly direction and increased in force to telephone the facts to the supervisor at Sisson, which was selected as the "key" station. By placing one of the anemometers at Sisson, at an elevation of 3,555 feet, and another on Mount Eddy, about 8 miles west, at an elevation of over 9,000 feet, it is hoped that we may be able to correlate the velocities at the higher and lower levels.

I beg to report that this work has received careful consideration not only on the part of this office but also by

[1] Extracts from report by the district forecaster, Portland, Oreg., of Nov. 26, 1915.
[2] Extracts from reports by the district forecaster, San Francisco, Cal., of Nov. 29, 1915, and Feb. 23, 1916.

consultations with the district forester and the several supervisors in this district. There are many factors deserving of careful study and investigation which are conducive to starting forest fires and also to aggravating a fire already started.

The condition of the humus on the forest floor is a matter of vital import. No serious fire may be expected until after it has become quite dry, and probably the rate of evaporation at the surface is proportional to the fire hazard. Assuming this, we must next determine what meteorological factors can be safely taken as an index for the rapid drying of the forest floor. These, I believe, can safely be reduced to two, a drying wind or very warm weather. A north or northeast wind, although light, causes a decided drop in the humidity in California, and consequently a rapid drying of the forest floor; also high temperatures in this State are invariably accompanied by low humidity, causing the same rapid drying condition. If the temperatures are only moderately high, they will have to continue for several days before the humus is sufficiently dry to become dangerous. Any combination of the above-named conditions will be conducive to hastening the drying process and raising the fire hazard.

Once a fire has started, dry winds and warm weather greatly tend to increase its energy, the increase being proportional to the velocity of the wind and intensity of the hot spell. Cloudy weather, particularlly if accompanied by winds coming off the ocean and carrying a high percentage of humidity, are factors that in a marked degree mitigate against the rapid spread of a fire. A shower of 0.25 inch will, in nearly every case, bring a fire under perfect control, and in many cases even 0.10 inch will so reduce a fire's energy that it can be easily handled.

From the forester's standpoint there are other serious factors to be considered, among which are the character of the undergrowth and its density, the topography of the country and the availability of men for emergency service and their transportation to the fire zone. His fire hazard also increases as the number of people frequenting the forests increases, and from many other causes.

In addition to the information shown on the weather map and from special observations, whenever a ranger on lookout duty stationed on some high peak, observes the wind to be blowing from the north or northeast at a rate of 10 miles per hour for one hour, he telephones the supervisor to that effect, and if two such reports are received, the supervisor immediately telephones the district forester's office in this city, and he in turn notifies the district forecaster. If it is decided to issue a fire warning, the district forester is advised of the necessity for such warning, given the forecast and the sections to which it applies. The forester then distributes the warning to his supervisors, who in turn telephone it to all rangers and make preparations for any emergency that may arise.—*G. H. Willson.*

Chicago, Ill., District.[3]—In 1914 six warnings were sent to northern Minnesota and one to western Montana.

In 1915 five warnings were sent to northern Minnesota, all during the month of June. At the request of the section director at Minneapolis messages, even for moderate breezes, were sent to the foresters during the critical season in June.

"Fire-wind" warnings have not been issued to any great extent during the past two seasons to the States in this district listed for them, viz, northern Minnesota, western South Dakota, Montana, and Wyoming. This is partly due to the absence of deep lows or strong winds during the critical season, and to more than the usual rainfall, especially in 1915. The messages have been sent during the periods specified by the section directors, being discontinued upon their telegraphic request.

I have no information upon the subject of benefits from the warnings issued.—*H. J. Cox.*

[3] Extracts from report by the district forecaster, Chicago, Ill., of Nov. 23, 1915.

DROUGHTS AND HOT WEATHER.[4]

By E. A. BEALS, District Forecaster.

[Weather Bureau, Portland, Oreg., December, 1915.]

When the forest litter is wet it is hard to start a forest fire; when dry it is easy, therefore a prerequisite of a forest fire is a drought. Drought has never been defined in definite terms, but the common meaning is long-continued dry weather, especially so long continued as to cause vegetation to wither. Vegetation withers when deprived of moisture, and, while lack of rain is essential, another important factor is evaporation. When evaporation is rapid, the injurious effects of dry weather are intensified, and when it is slow they are mitigated. The amount of evaporation depends on a number of things, the most important of which from a meteorological standpoint are humidity, temperature, wind, and barometric pressure (3).

Evaporation is accelerated when the humidity and pressure are low and the temperature and wind are high. As there are no means of correctly measuring evaporation from a forest cover, it is necessary to consider the factors causing rapid evaporation in order to determine the extent of the fire danger to which a forest is exposed. Of these factors, which consist of low humidity, low pressure, high temperature, and high wind, the Weather Bureau furnishes the public with predictions of the two most essential, viz, high temperatures and high winds.

Of the remaining factors, that of low pressure exerts a minor influence on evaporation, and while not specifically included in the forecasts, the areas of low pressure are usually described in the notes accompanying weather maps, and the maps show their location as well. When fire-weather forecasts are made, the locations and movements of both the low and high pressure areas are included in each forecast.

No attempt has been made to predict humidity, but it is understood by the public on the Pacific slope that when hot weather prevails the humidity will be low, and a prediction of hot weather during a drought practically covers both elements.

HIGH WINDS.

High winds in combination with drought cause far greater losses through their influence in fanning the flames than in their effect on evaporation, therefore they should be treated separately, which leaves high temperatures during droughty periods as one of the principal elements requiring attention when making predictions of weather favorable to an increase of forest fires.

Should the wind increase to a moderate breeze, or stronger, as defined by the Beaufort scale, it is almost impossible to extinguish a forest fire. Moderately high winds from any direction are dreaded by forest-fire fighters, but in the Pacific States those from an easterly direction are dreaded more than those from any other direction, as they are invariably parching winds that sap the vitality of the trees, and rapidly dry out the leaf litter and duff.

[4] Extracts from paper, "Forecasts of weather favorable to the increase of forest fires," read before the Pan-American Scientific Congress at Washington, D. C., Dec. 30, 1915.

There are three classes of winds on the Pacific slope that blow at times at as great or at a greater velocity than a moderate breeze. They are cyclonic winds, mountain and valley breezes, and land and sea breezes. Both the mountain and valley and the land and sea breezes are greatly modified by those due to cyclonic action.

The cyclonic winds can be forecast without much difficulty, but the variations that take place, both in their direction and velocity, on account of the influence of the other breezes, as well as the deflections that take place because of topography, usually cause unsatisfactory verifications. It is the cyclonic winds that are now being predicted when it is thought they will be sufficiently strong to be the dominating factor, and by sufficiently strong is meant winds having a velocity of 15 or more miles an hour.

FIRES CAUSED BY LIGHTNING.

The only uncontrollable cause of forest fires is lightning, which, as everyone knows, is the distinctive feature of thunderstorms. One would think that the rain attending the thunderstorm would put out any fire that might be started by lightning, but often there is so little rain that this is not the case.

Forest Service statistics show that for the period from 1908 to 1914, inclusive, there were 3,548 fires known to have been started by lightning in the national forests in Oregon, Washington, Alaska, Montana, Idaho, Wyoming, Colorado, and the western portion of the Dakotas, which makes an average of slightly over 500 a year.

Very little has been done by the Weather Bureau toward predicting the thunderstorms that are accompanied by the lightning which sets fire to forests. Rapid vertical convection of humid air is essential to the generation of thunderstorms, and Prof. W. J. Humphreys (4) gives three ways in which this circulation can be established, as follows:

(*a*) Strong surface heating, especially in regions of light winds; a frequent occurrence.

(*b*) The overrunning of one layer of air by another at a temperature sufficiently lower to induce convection; well-nigh the sole cause of ocean thunderstorms and also of frequent occurrence on land.

(*c*) The underrunning and consequent uplift of a saturated layer of air by a denser layer; a frequent occurrence to a greater or lesser extent, and presumably therefore at least one of sufficient magnitude to produce a thunderstorm.

The first method is the most favorable for thunderstorms in mountainous regions where the forests are situated and weather forecasting is not far enough advanced to make satisfactory predictions of this class of storms. Thunderstorms generated by the second or third method can generally be predicted, but as they seldom occur during the season for fires in the forested sections west of the Rocky Mountains there is not often an occasion for predicting them.

To arrive at a better understanding of the kind of weather that should be predicted for the forest people, my method was to ascertain the dates when a number of fires had occurred in the past and then prepare charts showing the weather conditions prevailing from 6 to 24 or more hours prior to the fires. Quite a number of these types are kept at the Portland weather office, where they are available for reference purposes at a moment's notice. Four of these charts were prepared on a small scale for this occasion, as well as eight others, showing conditions upon which actual forecasts were based during the last two fire seasons.

From the charts that have been prepared to show weather conditions just preceding some of the large fires in the past, it is learned that in every case the fires did not become dangerous until after a small increase in the velocity of the wind had taken place. This small increase in the velocity of the wind can usually be predicted sufficiently far enough in advance to make the forecasts of great value to the forest fire fighters.

Winds causing the rapid spreading of forest fires are usually those associated with cyclones, except in the Pacific States where they are as a rule those associated with anticyclones. The latter type is considered the most dangerous, as the winds attending anticyclones on the Pacific slope during the summer months are always very dry and warm.

ACTUAL FIRE-WEATHER FORECASTS.

Although the forecasting of fire weather began in the North Pacific States during the summer of 1913, it was not until the summer of 1914 that sufficient study had been given the subject to warrant forecasts of this class being systematically made.

Reports were received from the field showing that these forecasts were for the most part verified, and that they were of benefit to the fire fighters, but no one knows better than myself that there is room for improvement, and more study will have to be given the subject before any great advancement can be made in predicting weather favorable for the spread of forest fires.

PRESENT CONDITION OF THE FIRE-WEATHER FORECASTING SERVICE IN THE NORTH PACIFIC STATES.

The present condition of the fire-weather forecasting service in the North Pacific States can be summed up as follows:

The season for forest fires includes July, August, and the first half of September, though fires sometimes occur in May and June.

When dry weather has prevailed for a sufficient period to make forest fires possible, which question is determined empirically, forecasts are issued when the conditions are favorable for fresh breezes or for a spell of hot weather.

Special pains are taken to forecast fresh or brisk north, northeast, or east winds, as they are always attended by low humidity and are more dangerous on that account than those from any other direction.

Each forecast is worded to show (*a*) position of the dominating high and low pressure areas, (*b*) apparent direction and speed of their movements, (*c*) character of winds and temperature expected for as long a period ahead as possible, and (*d*) such cautionary advice as is thought necessary.

Fire-weather forecasts are telegraphed at Government expense to district foresters, and to the chief wardens of forest protective associations, and by them distributed to their men as they see fit.

What is needed to improve the service.

In advancing opinions as to what should be done to improve the service, the conditions in the North Pacific States alone are considered. Other districts very likely will require treatment modified according to their special needs.

Knowledge regarding the weather that prevails in the forests is meager, as the reporting stations are all in the valleys, often many miles away, and the few cooperative stations in the forests are only equipped with rain gauges and thermometers. The first essential, therefore, is to divide the territory into convenient units, when a careful meteorological survey of each should be made.

This survey should show during the forest-fire season the prevailing winds, their hourly velocity, the frequency of gales, daily precipitation, periods of drought measured on a uniform scale, the daily a. m. and p. m. humidity, the maximum and minimum temperatures, and if possible the daily rate of evaporation. In addition, observations of thunderstorms and of other natural phenomena should be made. These data, when obtained, should be graphically represented on charts and correlated with those forest conditions that tend to increase or diminish the fire hazard, such as inflammability, risk, controllability, liability, and safety. When this has been done it will be possible to determine when an emergency exists which will make necessary the dissemination of fire-weather forecasts, should the weather conditions from that time on justify their being made. Also there will be data available which will enable the forecaster to adjust his forecasts to meet conditions in more restricted localities than at present.

As an illustration of what could be done along these lines, an extract from an unpublished report (6) by Forest Supervisor W. L. Merritt and Mr. W. J. Sproat, from data obtained without instruments in the Deschutes and Deschutes division of the Paulina Forests, follows.

1. The normal wind movement seems to be from an eastern direction in the morning and early forenoon, and from a western one in the afternoon. Severe winds almost invariably blow from some westerly direction, and not from the east, as has sometimes been stated. General eastern winds apparently are not dangerous in this locality.

2. Generally the wind dies down at night and does not become severe until about 10 a. m. the next day. Every effort should be made, therefore, to control fires before that hour of the morning.

3. It is thought the winds are not extremely dangerous until after the velocity exceeds about 15 miles an hour. When the rate is this amount it is extremely difficult to control fires that may be burning.

4. A study of the chart of general conditions in Oregon and a general knowledge of the topography and conditions throughout the eastern portion of the State seem to indicate that severe windy periods come after the high desert region has become excessively heated during the period of high temperatures, causing low-pressure areas and resulting in a strong wind movement toward the east.

5. Although no smoke records were kept last summer, it was our general observation that smoky conditions were coincident with severe windy periods, no doubt due to the fact that eastward air movements brought smoke from the west slope of the Cascade Divide.

6. It is probable there is some relation between lightning storms and the causes which precede severe windy periods. Since no records were kept of lightning storms last summer, however, this point can not be stated with certainty. Lightning records will be kept during the coming season.

In another part of the report by Messrs. Merritt and Sproat, it is stated that "Although the wind records for that day did not show that the conditions were bad, the wind really blew very hard at the fire itself."

It is well known that forest fires cause strong convectional currents and that inflowing surface winds of greater or less velocity result therefrom (7). This interesting phenomenon should be thoroughly investigated, as next to nothing is now known regarding the extent of area surrounding fires that is thus affected.

Dry periods are not classified and published by the Weather Bureau, and, furthermore, there are at present only a few places in the forests where a record of the weather is kept; therefore very little is known regarding actual periods of drought in the timbered regions west of the Rocky Mountains. That rainfall on the Pacific slope increases with altitude is well known, also that the forests in that section are nearly all located on the sides of the mountains, consequently the rainfall in the valleys some distance away is a poor guide upon which to base an estimate of the amount that falls in the more elevated regions where the forests are situated.

The establishment of weather stations on mountain slopes where there are forests is difficult of accomplishment, unless the observers are paid a salary sufficient to make the observation work their chief occupation, and to do this would so increase the cost as to make the service prohibitive. There are so few settlers in forested regions that it is seldom possible to obtain the services of a good observer who is willing to undertake the work of keeping a weather record without pay. The forest rangers are not available, as the nature of their work keeps them away from their homes a good part of the time and particularly during the season for forest fires, when it is most important that no break occur in the weather records.

It is possible, however, from time to time to obtain good observers in the forests who are willing to serve without pay, and when such an opportunity occurs it is believed a weather station should at once be established, as the cost of the instruments and blanks is small when compared with the value of the data obtained.

Temperature data obtained in the cities will represent fairly well the conditions prevailing in the forests, at least to the extent that when the weather is warm in the cities it will be relatively warm in the forests, and vice versa. It will not be necessary, therefore, to establish as many temperature-recording as rainfall stations.

The percentage of fires started by lightning is large, but the hazard from this cause is not so great as indicated by the statistics, as lightning seldom sets fire to a green tree (8). After the snags and stubs are removed the danger of forest fires from lightning will be greatly reduced. It will, however, take many years to remove the dead trees from forested areas, and careful records of thunderstorms should be made for some time to come.

Thunderstorms in mountains are most frequent during the afternoon, and they are especially liable to occur near the end of two or three days of hot weather (4). After sufficient data have been secured it may be possible to predict the days when and the places where they are most likely to occur.

CONCLUSIONS.

According to United States Forest Service statistics (9), forest fires in the United States have caused an annual loss of about 70 human beings, the destruction of trees worth at the very least $25,000,000, and the loss of stock, crops, buildings, and other improvements to the amount of many millions more. Forest fires under the present system of control seldom cause much loss, except when the wind increases to 15 miles or more an hour, when it is impossible to extinguish them.

Advanced information of when to expect winds of this character will enable those in charge of putting out forest fires to increase their fire crews, stop burning permits, and to take other precautionary measures which might be the means of preventing destructive fires; therefore it is believed that the effect of weather on forest fires is deserving of careful study by meteorologists in all parts of the world, and especially by those in the United States, that a way may be devised to improve the forecasts of

wind, as well as the forecasts of other elements that cause an increase in the number of forest fires.

REFERENCES.

(1) Encyclopedia Americana, Vol. VII, Forestry in the United States
(2) Signal Service Notes, No. 1, Report on the Michigan Forest Fires of 1881.
(3) Meteorology, by W. I. Milham, p. 193.
(4) The Thunderstorm and its Phenomena. MONTHLY WEATHER REVIEW, June, 1914, p. 348.
(5) Elementary Meteorology, by W. M. Davis, p. 243.
(6) Report on Wind Movements and their Relation to Forest Fires, by W. L. Merritt and W. J. Sproat (unpublished manuscript).
(7) The Value of Weather Forecasts in the Problem of Protecting Forests from Fire. MONTHLY WEATHER REVIEW, February, 1914.
(8) The Spell of the Rockies, by Enos A. Mills. 1911.
(9) Forest Fires. Forest Service Bulletin 117.

HOW THE WEATHER BUREAU CAN HELP.[5]

By E. A. BEALS, District Forecaster.

[Weather Bureau, Portland, Oreg., October, 1915.]

To estimate the probable intensity of a forest-fire hazard we need to begin our analysis of the weather as far back as the preceding October or November, especially as regards snowfall in the mountains. The destructive fires in 1910 were primarily due to a deficiency in snowfall during the winter of 1909–10, which was followed by a warm March that caused most of the snow to disappear by the 1st of April, or two months earlier than usual. The rains during the warm months that followed were light. The humus in the forest became dry, and fires were prevalent early in the year. They had obtained good headway in many localities long before the season for them had arrived.

During the winter of 1914–15 the snowfall was even less than in 1909–10, in fact, every report received last spring showed less snow on the ground than in the last 20 or more years. The beginning of this season was, therefore, more inauspicious than in 1910. They say the Lord favors the shorn lamb, and He must have had the lumber interests in mind when He gave the parched earth such bountiful showers last May and July (1915). It was the excess of rain in those two months that saved us from what might have been as bad a season for forest fires as any we have had in recent years. We were also favored by not having any very high winds to contend with during the height of the fire season, which did not really begin until August, and the worst part was over about September 10.

June, 1915, was drier than was June, 1914, in Oregon, Washington, and Idaho, and it was a little warmer in the first two States and a trifle cooler in Idaho. July, ordinarily dry, was a wet month in 1915, with 280 per cent of the normal rainfall in Oregon, 130 per cent in Washington, and 145 per cent in Idaho. July was also cooler than last year in all three States. If the following August had only followed July's example, we should have had no serious trouble with fires this year; but that month was not only about as dry as it was a year ago, but, in addition, it was considerably warmer. It was the fires started during this month that caused the greatest apprehension, and they taxed the fire-fighting strength under the control of some of your wardens and supervisors to their utmost.

Our forecasting in 1915 followed the same lines as in 1914, and while not up to the mark we have set for attainment, I am more convinced than ever the service is of help to the fire fighters, and it promises to be of value in lines not thought of before this season.

Three "sets" of fire-weather forecasts were issued—one in July, one in August, and one in September. The forecasts issued in September were verified in only a few places, while the others were fairly reliable, especially the one in August, which covered the worst period for fires in western Washington and northwestern Oregon (the territory to which it was limited).

Another way whereby the Weather Bureau can help those having charge of the work of putting out forest fires will be in the advice we are able to give regarding the daily weather conditions. If the fires are under such control that the conditions would be shaky if the winds increased, the question comes up whether to lay the men off or hold them for the contingency of high winds arising in the near future. Also we may have a local rain which would lead the man on the ground to believe all immediate danger has passed, and he would let his men go, when as a matter of fact the rain was insufficient and only temporary relief was obtained. Before he could get his men back losses might occur that would have been prevented if he had held them. In these small ways I feel sure we can be of help to those in doubt as to the procedure that should be taken.

Next year we hope to send "hot weather" forecasts to every post office in the neighborhood of forests, at least in the three Northwestern States. They will be printed on post cards and, besides the forecasts, will contain words of caution to campers and others who visit the forests about starting and putting out camp fires, etc. We hope that this card, issued in conjunction with the forecasts, will be posted in the country post offices and that it will help to impress the public with the importance of taking more care in these matters. Many fires obtain their start through sheer carelessness, and the public should have their attention called to preventative measures from as many angles as possible. The weather forecast will first attract the eye, and when the announcement "hot weather" is read the corollary of the increasing fire hazard will be impressed upon the readers by the accompanying notes on the caution that should be exercised by campers to prevent the spreading of their fires. If, through this card, only one "class C" [6] fire is prevented it will much more than pay for the cost of the service.

Perhaps the most important step taken this year which will operate toward the efficiency of the fire-weather forecasts is the inauguration of nine lookout stations in the national forests of Oregon and Washington, which have been equipped with instruments for measuring and recording the velocity of the wind, the humidity, temperature, and rainfall. We hope the records kept at the high altitude of these stations will give information that will enable us to increase the time limit ahead of the occurrence of changes in the weather. This is important, for every hour in advance of a change to worse weather permits more preparation to avert the threatened damage.

[5] Extracts from paper "Fire-weather forecasts: where and how they prove effective," read before the Forest Industry Conference at San Francisco, Cal., Oct. 19, 1915.

[6] The United States Forest Service classifies forest fires, in its annual statistical statements, according to the area burned and designates the classes as follows:
Fires of class A are those covering less than one-fourth acre.
Fires of class B are those covering not more than 10 acres.
Fires of class C are those covering more than 10 acres.
Prior to 1912 fires of class B covered areas under 5 acres, and class C fires covered areas of 5 acres and over.—C. A., jr.

The instruments for these lookout stations were furnished mostly by the Forest Service, which also supplies the men to operate the stations. The records are kept in accordance with Weather Bureau instructions, and copies are furnished my office for study purposes. We shall have to collect data for several seasons before we shall be sure just how they can be put in use to the best advantage, for one year's record is no criterion of what to expect the following year. The weather is never alike in any two seasons, but we can surely formulate certain postulates that will apply to all years.

The great advantage of the lookout stations is their elevation. They are all located nearly a mile above sea level, and the changes that take place in the weather may first appear in any part of the circulatory system which includes both the high and low strata of the atmosphere. These stations are connected by telephone with trunk lines. Reports can be received from them almost at a moment's notice, and as often as required. This year only two of the lookout stations reported to our office, and while the observations were mostly negative in character the information was of value. As soon as we can compare the high-level with the low-level observations we shall have more data covering the third dimension of our problem, which heretofore we have attempted to solve on the basis of two dimensions, except as to the information obtained from the movement and character of clouds.

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, MARCH, 1916.

By ALFRED J. HENRY, Professor in Charge River and Flood Division

[Dated: Weather Bureau, April 29, 1916.]

Mississippi.—The flood in the lower Mississippi, which began in the latter part of January, 1916 (see this REVIEW for that month), gradually subsided during March, 1916, the river at Vicksburg, Miss., passing below flood stage on the 17th. Six days later it dropped below the flood stage at New Orleans, after being continuously in flood at that station since January 31, 1916, a period of 52 days. At Vicksburg the river was above flood stage a period of 63 days, one day longer than in 1912.

Fortunately the rainfall distribution during both February and March, 1916, in the watershed above Vicksburg was such as to permit a steady decline of the flood waters in practically all parts of the basin. A large part of the precipitation of March in northern districts was in the form of snow, as a consequence of which there was a fairly heavy snow cover in upper Michigan, northern New York, and northern New England as late as the 27th. Relatively high temperatures and moderate rains in the middle Mississippi Valley on the 26th–27th caused a light swell to pass down the river between Keokuk, Iowa, and Louisiana, Mo., as shown in Table 1. This swell did not reach the magnitude of a flood in the main river above Keokuk, Iowa, but the total precipitation over a region embracing northeastern Iowa, northwestern Illinois, and southwestern Wisconsin from the 21st to the 26th was great enough to produce flood stages in the tributary streams which subsided almost as quickly as they rose. The stage in the Galena River of Illinois is said to have been at least a foot higher than ever before recorded. The railroads in the flooded section suffered considerable loss to roadbed and tracks and also from a general suspension of traffic for three or four days. The damage in the flooded section probably amounted to $50,000, of which about one-third was sustained by the railroads. Two lives were lost.

The warm weather and the rains mentioned in the above paragraph were associated with low No. VIIIA, Chart III, this REVIEW. The same low, as it advanced over Michigan, was attended by rains averaging about 2 inches in depth over the State south of the Straits of Mackinac. This amount of rain and the melting of 3 to 4 inches of freshly fallen snow resting upon a frozen soil, caused a very rapid and excessive run-off and severe floods all over the Lower Peninsula. The flood in the Grand River at Grand Rapids, Mich., was the greatest since 1905, with the single exception of the April, 1912, flood. The flood in the Saginaw River and its tributaries was complicated by ice jams at several places that caused a temporary damming of the current and overflow of the lowlands that would otherwise have escaped. It is reported that thousands of acres of agricultural land in the Saginaw Valley were under from 2 to 8 feet of water, thus necessitating the removal of stock to higher ground. The damage to the land was probably very small, but a number of farm buildings will have to be renovated and put in order before being again occupied. Some bridges were swept away and there was a suspension of railway traffic on the Jackson division of the Michigan Central, the Grand Rapids division of the Pere Marquette, also on the Grand Trunk for several days.

The weather conditions as described above also produced floods in the Fort Wayne (Ind.) and Columbus (Ohio) river districts. All of these floods were forecast. The stages reached in the Grand Rapids and Saginaw districts of Michigan and the Fort Wayne district of Indiana are given in Table 2, and for the rivers of Ohio in Tables 2 and 4.

Missouri River flood in the vicinity of Yankton, S. Dak.—A severe flood or overflow of the lowlands on both sides of the river occurred between the 7th and 13th, resulting in a very considerable loss of live stock, stored crops, and hay in stacks, also damage to farm buildings amounting probably to slightly more than $200,000. Damage to railroad tracks and roadbed and to county roads and bridges will increase the total loss to about $250,000.

The ice in the Missouri River during the winter of 1915–16, was somewhat thicker than usual. A warm spell in February caused the ice to break up at Sioux City, Iowa, and go out as early as February 21. At Yankton the river was nearly free of ice on February 23. At Pierre, the most northerly reporting station, the ice broke up February 24, but evidently gorged a short distance below that place and held until March 4, nine days later, when ice began running on an 18.6-foot stage at Pierre.

At Chamberlain, S. Dak., the next station below Pierre, the ice broke up on the 5th at a stage 5 feet below flood stage. At Running Water, S. Dak., just below the mouth of the Niobrara, heavy ice was running on the 7th, with a stage of 18.8 feet, or nearly 3 feet above flood stage. The crest of this wave evidently reached Yankton, S. Dak., early the same day. At that point the river was bankful and carried a heavy burden of ice during the forenoon of the 7th, but it began to recede in the afternoon, falling several inches. Soon, however, it turned and again began to rise, adding 2 feet to a stage that was already serious. The gorge below Yankton continued to hold throughout the 8th to 11th, but gave way on the 12th. Meanwhile the overflow and backwater had created a very serious condition along the river between Springfield and Vermillion, similar in many respects to the memorable overflow of April, 1881, also caused by ice gorges. Table No. 3 shows but a single flood stage in connection with the very destructive overflow at and near Yankton.

Ohio River.—During February and March a considerable amount of snow had accumulated over the watersheds of the Allegheny and Beaver Rivers and a less amount over the watershed to the east of Pittsburgh. The low-pressure system No. VIII A, Chart III, before referred to as causing floods in Arizona, lower Michigan, and the middle Mississippi Valley, in its east-northeast course, was attended by relatively warm weather in the Pittsburgh, Pa., district on the 25th, continuing until the end

of the month. The Allegheny and the Beaver Rivers began to rise, due to snow water, on the 26th. On the two succeeding days moderate rains fell over the district. The Allegheny and Beaver were both above the flood stage but the former failed to reach flood stage at Pittsburgh by 0.2 foot, doubtless due to a fall in temperature that checked the snow melting above Pittsburgh.

The cessation of the rains on the 29th, together with the fall in temperature noted above, destroyed whatever chance of a severe flood then existed and, as it turned out, only a small flood resulted. The flood stage was not reached on the Ohio at Wheeling, but stages slightly above flood were reached from Parkersburg to Cincinnati and again in the Evansville district, but not in the intervening Louisville district except at a single station, Cloverport, Ky., nor at Cairo, Ill., although a stage of 44.5 feet, lacking 0.5 foot of flood stage, was reached at that place on April 8, 1916. This slight swell from the Ohio passed down the Mississippi during April but was not reinforced by flood waters from other tributaries of the main river and served mainly to prolong the period of high water below Memphis. The lower river, after falling to 35 feet at Vicksburg, began to again rise and reached a second crest of 45.2 feet on April 26, after which date a fall set in.

Susquehanna River.—In the watershed above Binghamton, N. Y., on the north branch of the Susquehanna the average depth of the snow cover on March 23 was 24.7 inches, with a water equivalent of about 35 per cent. During the ensuing week the snow cover disappeared at an average rate of an inch daily and considerable water found its way into the streams. Fortunately the weather conditions during the closing days of the month were favorable to a gradual and moderate run-off. Flood stages in the Susquehanna and the Hudson are shown in Table 5. The weather conditions over the watershed of the Hudson were similar to those which prevailed over the Susquehanna watershed during the closing days of the month. The most noteworthy feature was the absence of heavy rains, which greatly mitigated the flood conditions on both rivers.

In the Harrisburg district of the Susquehanna, which includes both the north and west branches of the river below Binghamton, and the Juniata, the ice broke up and went out on moderately high stages. The rainfall in this district was also light except on the 28th and, all in all, the breaking up of the ice during the spring of 1916 was attended by the minimum amount of flooding.

The property loss in the Binghamton district was about $5,000; in the Harrisburg district probably as much as $200,000, a large part of which was in the loss of wages of employees, due to the shutting down of various industrial plants.

Rivers in the Denver, Colo., district.—The prevailing mild temperatures during the month melted practically all snow in unprotected localities below 8,000 feet. All streams were swollen, and in localities in the mountains on the western slope the stages reached were almost as high as the crest stages of last year.

Salt River of Arizona.—A low-pressure system, No. VIII A of Chart III, moving eastward passed north of Arizona and caused a two-days' rain over the State and doubtless the melting of some snow at the higher altitudes. The Salt River reached and passed flood stage at Tempe on the 24th, but the rise soon subsided. The damage was nominal.

Willamette River.—Heavy rains during the closing days of the month, in conjunction with a high stage in the lower Columbia, conspired to produce flood stages in the Willamette and other Oregon rivers, as shown in Table 6. Owing to the advance notice given of this flood the damage was nominal.

Flood losses during March.

Missouri in South Dakota and Nebraska	$250,000
Susquehanna	205,000
Mississippi in Iowa, Illinois, and Missouri	187,600
Total *loss*	642,600
Estimated *saving* by warnings	30,500

TABLE 1.—*Floods in the upper Mississippi River and tributaries, March, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Mississippi	Keokuk, Iowa	14.0	28	[1] 5	16.4	Mar. 31
Do	Warsaw, Ill	17.0	28	[2]	19.0	31
Do	Quincy, Ill	14.0	28	[2]	18.0	31
Do	Hannibal, Mo	13.0	28	[2]	18.2	31
Do	Louisiana, Mo	12.0	29	[2]	15.8	31
Wisconsin	Knowlton, Wis	12.0	31	[2]	14.3	31
Des Moines	Ottumwa, Iowa	10.0	27	[2]	10.7	27
Do	Boone, Iowa	12.0	27	28	15.5	27
Illinois	Morris, Ill	13.0	28	29	13.0	29
Do	La Salle, Ill	18.0	26	[2]	22.6	29
Do	Peoria, Ill	16.0	30	[2]	17.2	31
Do	Beardstown, Ill	12.0	1	19	14.7	1
Do	do	12.0	28	[2]	13.0	31

[1] April. [2] Continued into April.

TABLE 2.—*Floods in the rivers of the Great Lakes drainage basin, March, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Sandusky	Upper Sandusky, Ohio	13.0	27	28	14.4	Mar. 28
Do	Tiffin, Ohio	10.0	27	29	12.0	29
Do	Fremont, Ohio	10.0	27	28	11.3	27
Maumee	Fort Wayne, Ind	15.0	27	31	18.3	30
Do	Napoleon, Ohio	10.0	28	30	12.2	29
Auglaize	Defiance, Ohio	10.0	28	29	12.2	29
St. Joseph	Montpelier, Ohio	10.0	27	30	13.2	28
Saginaw	Saginaw, Mich	19.1	28	31	24.3	31
Shiawassee	Owosso, Mich	8.0	28	29	8.3	29
Do	Chesaning, Mich	15.0	28	28	15.1	28
Flint	Flint, Mich	14.0	28	31	18.5	29
Do	Fosters, Mich	18.0	29	29	18.0	29
Cass	Vassar, Mich	14.0	28	31	18.9	30
Tittabawassee	Midland, Mich	12.0	27	31	23.4	28
Do	Paines, Mich	20.0	29	29	20.2	29
Chippewa	Mount Pleasant, Mich	11.0	27	31	13.9	29
Pine	Alma, Mich	7.0	27	31	10.7	28
Grand	Eaton Rapids, Mich	6.5	28	28	6.5	28
Do	East Lansing, Mich	7.5	26	31	11.6	27
Do	Lansing, Mich	10.8	27	30	14.5	28
Do	Ionia, Mich	22.0	28	30	23.5	29
Do	Grand Rapids, Mich	11.0	28	31	15.8	30

TABLE 3.—*Floods in the Missouri River and tributaries, March, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Missouri	Williston, N. Dak	24.0	31	31	25.0	Mar. 31
Do	Bismarck, N. Dak	14.0	19	21	15.3	20
Do	Running Water, S. Dak.	16.0	7	7	18.8	7
Milk	Havre, Mont	9.0	8	17	17.2	12
Little Missouri	Medora, N. Dak	9.0	16	16	9.1	16
James	Huron, S. Dak	9.0	14	28	10.5	22
Grand	Chillicothe, Mo	18.0	27	29	21.1	28

TABLE 4.—*Floods in the Ohio River and tributaries, March, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Ohio	Beaver Dam, Pa	30.0	29	30	32.5	Mar. 29
Do	Marietta, Ohio	33.0	29	31	35.6	30
Do	Parkersburg, W. Va	36.0	30	31	37.1	30
Do	Point Pleasant, W. Va	40.0	30	31	43.0	31
Do	Dam No. 26 (Hogsett), W. Va.	46.3	31	31	46.3	31
Do	Catlettsburg, Ky	50.0	31	31	50.1	31
Do	Portsmouth, Ohio	50.0	30	31	53.2	31
Do	Maysville, Ky	50.0	31	31	51.4	31
Do	Cincinnati, Ohio	50.0	31	[1]3	53.2	31
Allegheny	Clean, N. Y	12.0	28	31	15.1	29
Do	Warren, Pa	12.0	29	31	14.0	30
Do	Franklin, Pa	15.0	29	31	17.1	29
Do	Parker, Pa	18.0	29	31	19.5	29
Do	Mosgrove, Pa	20.0	28	31	22.5	29
Do	Freeport, Pa	22.0	28	31	25.8	28
Do	Lock and Dam No. 3, Springdale, Pa.	27.0	29	30	29.8	29
Do	Herrs Island Dam, Pa	22.0	29	30	24.2	29
Clarion	Clarion, Pa	12.0	28	28	13.4	28
Stony Creek	Johnstown, Pa	10.0	28	28	10.5	28
Kiskiminetas	Saltsburg, Pa	8.0	28	28	8.7	28
Monongahela	Greensboro, Pa	20.0	22	22	20.5	22
Youghiogheny	Confluence, Pa	10.0	22	22	10.5	22
Beaver	Beaver Falls, Pa	10.6	27	27	10.8	27
Shenango	Sharon, Pa	9.0	26	30	12.0	28
Mahoning	Youngstown, Ohio	7.0	26	28	8.9	27
Muskingum	Zanesville, Ohio	25.0	28	28	25.1	28
Do	McConnelsville, Ohio	22.0	28	30	24.5	30
Do	Marietta, Ohio	32.0	29	31	37.1	30
Walhonding	Walhonding, Ohio	8.0	23	24	9.8	23
Do	....do....	8.0	28	29	11.2	28
Tuscarawas	Norris Point, Ohio	8.0	23	29	11.2	24
Do	Coshocton, Ohio	8.0	23	30	11.7	28
Scioto	Larue, Ohio	11.0	23	23	12.6	23
Do	....do....	11.0	27	27	13.2	27
Do	Prospect, Ohio	10.0	27	30	13.9	29
Do	Bellpoint, Ohio	9.0	27	28	12.2	27
Do	Dublin, Ohio	8.0	27	27	9.0	27
Do	Columbus, Ohio	17.0	27	28	19.8	27
Do	Circleville, Ohio	6.0	23	31	16.2	29
Do	Chillicothe, Ohio	14.5	24	24	16.6	24
Do	....do....	14.5	28	30	21.8	29
Olentangy	Delaware, Ohio	9.0	22	22	10.5	22
Do	....do....	9.0	27	28	11.4	27
Darby Creek	Fox, Ohio	8.0	27	28	15.1	28
Deer Creek	Williamsport, Ohio	8.0	27	27	8.7	27
Paint Creek	Paint Creek, Ohio	14.0	27	27	16.0	27
Little Miami	Kings Mills, Ohio	17.0	27	27	17.0	27
Miami	Tadmor, Ohio	12.0	28	28	13.6	28
Wabash	La Fayette, Ind	11.0	24	25	11.5	24
Do	....do....	11.0	28	31	14.8	30

[1] April.

TABLE 5.—*Floods in the Susquehanna and Hudson Rivers and tributaries, March, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Susquehanna	Oneonta, N. Y	10.0	30	[1]7	16.7	[1]2
Do	Bainbridge, N. Y	11.0	30	[1]7	16.9	[1]2
Do	Binghamton, N. Y	14.0	31	[1]3	16.5	[1]2
Do	Towanda, Pa	16.0	31	31	17.4	31
Do	Wilkes-Barre, Pa	20.0	29	31	24.8	31
Do	Williamsport, Pa	20.0	29	29	20.5	29
Do	Harrisburg, Pa	17.0	29	31	18.6	29
Unadilla	New Berlin, N. Y	8.0	31	[1]3	11.9	[1]2
Chenango	Sherburne, N. Y	8.0	31	[1]3	9.0	[1]2
Hudson	Albany, N. Y	12.0	31	31	12.2	31
Do	Castleton, N. Y	10.0	31	31	10.4	31
Mohawk	Tribes Hill, N. Y	16.0	29	29	18.2	29
Do	Schenectady, N. Y	15.0	31	31	16.0	31

[1] April.

TABLE 6.—*Floods in the rivers of the Pacific slope, March, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Columbia	Vancouver, Wash	15.0	26	30	17.1	28
Willamette	Oregon City, Oreg	12.0	27	29	12.9	28
Do	Portland, Oreg	15.0	24	31	19.5	28
Santiam	Jefferson, Oreg	10.0	26	27	10.0	26 & 27
Yamhill	McMinnville, Oreg	35.0	27	28	40.2	27
Clackamas	Cazadero, Oreg	8.0	26	27	10.0	26
Tualitin	Tualitin, Oreg	15.0	28	30	19.5	28
San Joaquin	Lathrop, Cal	17.0	23	24	17.7	23
Salt	Tempe, Ariz	7.0	24	27	11.4	24

TABLE 7.—*Miscellaneous floods during March, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Potomac	Cumberland, Md	8.0	23	23	8.8	23
Santee	Rimini, S. C	12.0	2	13	13.4	6 & 7
Do	Ferguson, S. C	12.0	1	17	13.4	8
Neosho	Fort Gibson, Okla	22.0	27	27	22.0	27
Rio Grande	San Marcial, N. Mex	11.0	24	24	14.3	24

MEAN LAKE LEVELS DURING MARCH, 1916.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Apr. 5, 1916.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.			
	Superior.	Michigan & Huron.	Erie.	Ontario.
Mean level during March, 1916:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.17	579.48	571.84	245.46
Above or below—				
Mean stage of February, 1916	−0.27	+0.01	−0.15	+0.05
Mean stage of March, 1915	+0.70	−0.12	+0.43	+0.19
Average stage for March, last 10 years	+0.60	−0.57	+0.07	−0.43
Highest recorded March stage	−0.11	−3.47	−2.01	−2.35
Lowest recorded March stage	+1.51	+0.37	+1.01	+1.16
Average relation of the March level to:				
February level	−0.2	0.0	+0.1	+0.2
April level	0.0	−0.2	−0.6	−0.5

RIVER-STAGE FORECASTS FOR THE ARKANSAS RIVER, DARDANELLE TO PINE BLUFF, ARK.

By HERMAN W. SMITH, River & Flood Division.

[Dated: Weather Bureau, Washington, Mar. 23, 1916; MS. received Apr. 14.]

The region for which river-stage forecasts have been worked out and are presented in the following paper is shown in the accompanying figure 1, which presents in outline the principal drainage channels and the positions of the main water partings of the lower Arkansas.

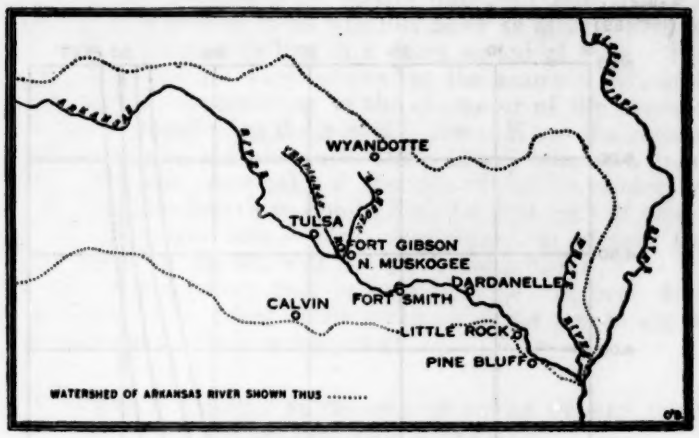


FIG. 1.—Location map of the lower Arkansas River.
["Verdigras" should be "Verdigris R."]

The distance from Fort Smith, Ark., to Dardanelle, Ark., is about 108 miles and the difference in elevation is 91.3 feet, giving a fall of 0.85 foot per mile. The distance from Dardanelle to Little Rock, Ark., is about 87 miles and the difference in elevation is 64.1 feet, giving a fall of 0.74 foot per mile. The distance from Little Rock to Pine Bluff is about 67 miles and the difference in elevation is 43 feet, giving a fall of 0.64 foot per mile.

The average time interval required for a rise to travel from Fort Smith to Dardanelle is about 1½ days; from Dardanelle to Little Rock, about 1 day; and from Little Rock to Pine Bluff about 1 day. There is a difference of about 50 per cent, possibly more, in the velocity of the current between a high and a low stage, the high stage of course having the greater speed, and this fact must be considered when making a river forecast.

TABLE 1.—*Flood stages and varying widths of the Arkansas at four points.*

Station.	Flood stage.	Width of river.	
		Low water.	Bankful stage.
	Feet.	*Feet.*	*Feet.*
Fort Smith, Ark.	22	600	2,320
Dardanelle, Ark.	20	800	2,340
Little Rock, Ark.	23	1,400	1,570
Pine Bluff, Ark.	25	610	1,600

The watershed on the north side of the Arkansas River in the Fort Smith and Little Rock districts is mountainous, and the streams fill quickly and run out rapidly: on the south side the watershed is more level and the streams rise more slowly and high stages continue longer.

40278—16——3

I. STAGE FORECASTS FROM RAINFALL ONLY.

As soon as a heavy rainfall is reported it is important to advise the public as early as possible as to the highest stage that may be expected in the river. This advice must be based upon the amount of rainfall that has been reported, since the forecast must be made before the water has had time to get into the rivers. If a sufficient number of stations were established to give an approximately correct average distribution of rain in the district, it would be possible to estimate closely the height of the resulting flood wave in the river. However, with the present small number of reporting stations it is possible to forecast the crest stage at Dardanelle about 2 days in advance, at Little Rock about 3 days in advance, and at Pine Bluff about 4 days in advance, and generally to within 1 or 1.5 feet of the stage that will be reached.

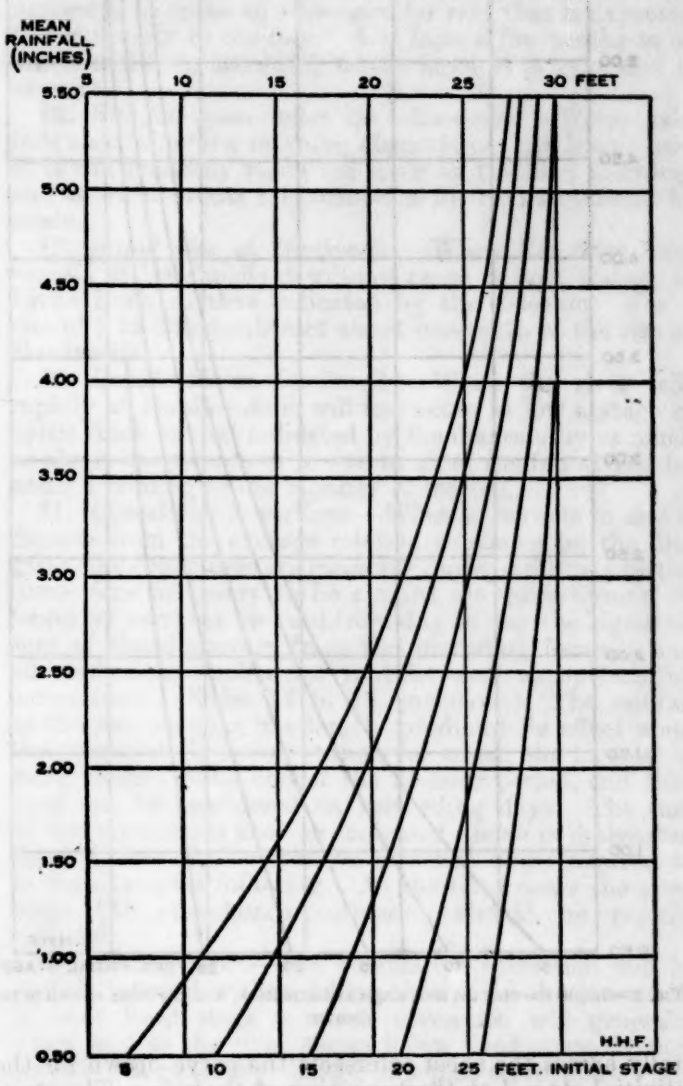


FIG. 2.—Graphs showing the crest stages at Dardanelle, Ark., for various mean rainfalls in the district. (The scale of figures 2 to 4 as here given is too small for a convenient working model. The horizontal scale should be about double that shown.)

Use of diagrams explained.—By plotting the mean rainfall over the district as ordinates and the crest stages as abscissæ, curves have been drawn for Dardanelle, Little

Rock, and Pine Bluff, Ark., for initial stages of 5, 10, 15, 20, and 25 feet. (See figs. 2, 3, and 4.)

In practice, the mean rainfall over the watershed is obtained by taking the arithmetical mean of the 24-hour rainfall as reported by telegraph from points in the watershed above the station for which the forecast is to be made. Thus if a forecast is to be made for Dardanelle, the mean rainfall is determined from the rainfall at Dardanelle and the amounts reported at stations in the Fort Smith district (see fig. 1). After determining the mean rainfall, enter the diagram on the left with the amount so found and note where the point of entry when carried horizontally across the sheet intersects the curve drawn for the "initial stage" at the beginning of the rain. The stage corresponding to that point is the crest stage to be expected at Little Rock 3 days later.

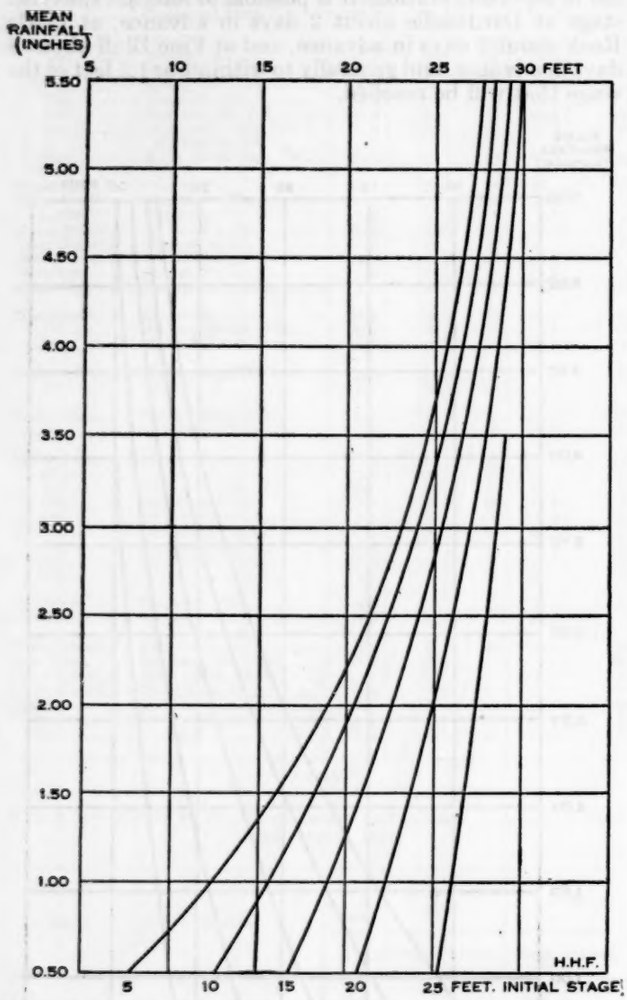


FIG. 3.—Graphs showing the crest stages at Little Rock, Ark., for mean rainfall in the district.

For initial stages other than those for which curves are given, interpolate between the curves.

Time period for crest stages.

1. Crest stage will generally reach Dardanelle in 2 days, Little Rock in 3 days, and Pine Bluff in 4 days after the rain if the rain has been general and evenly distributed.

2. If the rain is much heavier in the upper portion of the Fort Smith district than at Fort Smith and below, the crest stages will be about 1 day later than the times specified in the preceding paragraph.

3. If the rain has been much heavier at Fort Smith and below than above that place, the crest stages will be about 1 day earlier than the above, etc.

4. If the rainfall is much heavier in the vicinity of the point for which a forecast is made than above, the crest may occur on the same day as the rain.

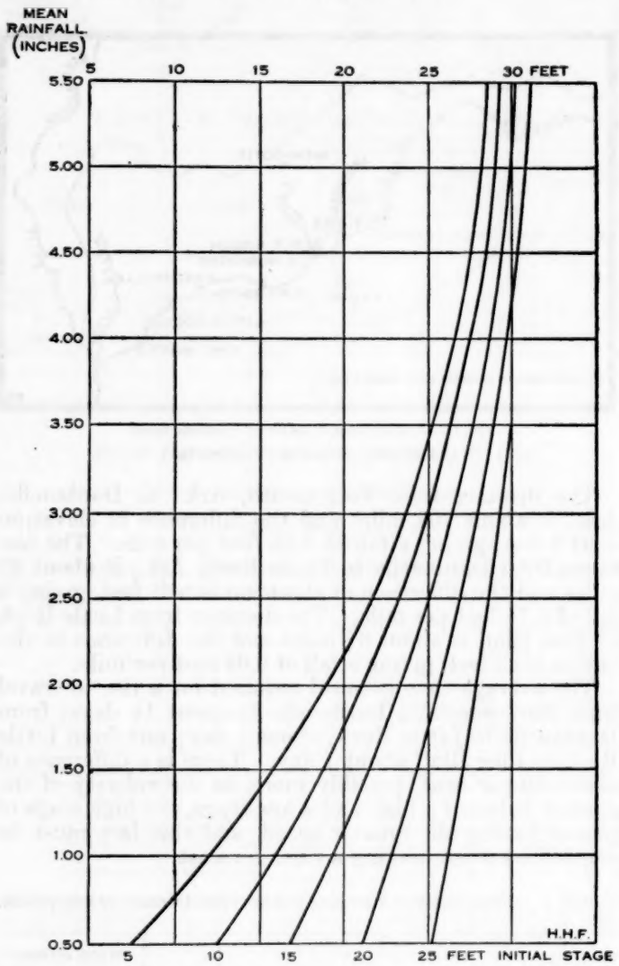


FIG. 4.—Graphs showing the crest stages at Pine Bluff, Ark., for mean rainfall in the district.

Distribution of rain.

5. When the rain begins over the upper portion of the watershed and moves down the river so that the water in the streams of the lower portion of the watershed reaches the river in time to meet the rise from upstream, it may cause a stage of from 1 to 3 feet higher than when the rainfall is evenly distributed, in point of time, over the entire watershed. However, the flood wave will be of shorter duration.

6. When the rain occurs first in the lower portion of the district and later in the upper portion, the crest may be from 1 to 2 feet lower than when the rain is simultaneously distributed, but the flood wave will be of longer duration.

7. When heavy rain occurs over only about one-fourth of the watershed use only about one-half to three-fourths the amount of heavy rain in making the district mean.

8. *Rain for several days in succession.*—When rain continues in the upper portion of the Fort Smith district for a longer time than it takes for the runoff to reach the station for which the forecast is made, use only three-fourths of the rain of the first day. If it continues for 2 days longer than the time period mentioned in paragraph **1**, use one-half of the first and three-fourths of the second day's rain.

9. *Rain continuing for several days.*—A rain that extends over several days will not have as much effect as an equal amount falling in a short period of time. The forecaster should vary somewhat the amount indicated by the curves according to the character of the rainfall.

10. *Rainfall when the ground is dry.*—When the ground is very dry or is under cultivation, it will take up a great deal of water, especially if the rate of fall be moderate; use only one-fourth to one-half of the first inch of rain.

11. *Excessive rain.*—With excessive rate of rain the condition of the soil will not have much effect.

12. When heavy rain is indicated for the next day, add from 1 to 2 feet to the stage indicated, according to the amount of rain anticipated.

II. RULES FOR DAILY FORECASTS OF RIVER STAGES, GAGE RELATIONS, AND RAINFALL.

In order to make a daily forecast of river stages based upon the stages of the river at a station above, the upstream station chosen should be located as nearly as possible at a distance which will require 24 hours or a multiple thereof, for the flood wave to travel from that station to the station for which the forecast is to be made.

The forecast for Little Rock is based upon the stages at Dardanelle one day earlier, and figure 6 has been constructed by plotting rising stages at Dardanelle as ordinates and the stages 1 day later at Little Rock as abscissæ and drawing a mean curve through them. The actual plotted rises are given with the curve in order that the forecaster may see the extreme variations from the mean curve. It will be seen that there is an extreme range of about 4 feet on either side of the mean curve for stages below 20 feet, while for stages above 20 feet the range is about half as large. This is due to the fact that the time interval is not exactly 24 hours, but is probably 30 to 36 hours at low stages and about 18 to 24 hours at high stages. It also depends on the origin of the rise, whether caused mainly by rains above Dardanelle, by a uniformly distributed rain, or by rain mostly at Dardanelle and below. In order to meet the special conditions as they arise, certain modifications are necessary, and the following rules have been prepared to aid in determining what modifications are necessary to meet these special conditions as they arise. In making corrections for rainfall the mean of the rain at Dardanelle and Little Rock is used.

13. *Tributary streams.*—If the tributary streams are low a great deal of water will back up into them and cause the stages on the main stream to be as much as 1 to 2 feet lower than the average as the rise passes downstream.

14a. *Rainfall when the ground is dry.*—When the ground is very dry, or is under cultivation, it will take up a good deal of water, and a rainfall of as much as 1 inch will have very little effect unless it falls in a very short time. Add about 0.5 to 1.5 feet for an inch of rain, according to the condition of the soil and the rapidity of the rainfall.

14b. If the rate of rainfall is very excessive the dryness of the soil will have very little effect, and almost the full allowance for rainfall should be given.

15. *Rainfall when the ground is moist.*—When the ground is moist and the river is below 20 feet, add from 1 to 2 feet for an inch of rain, according to the amount and the rapidity of the rainfall. For stages above 20 feet gradually lessen the amount of the correction for rainfall until at 25 feet, when but little should be allowed.

16. *Local showers.*—Local showers and thunderstorms are usually of very limited extent and will have but little effect, even when the precipitation is excessive.

17. *Rainfall anticipated.*—When heavy rain occurs in the vicinity of Little Rock early in the day it may cause a rise of 1 or 2 feet at that place the same day, and it is necessary to make an allowance for rain that is expected to occur early in the day. Add from a few tenths to as much as 2 feet, according to the amount of rain that is expected.

18. *Rainfall soon after the observation.*—When rain falls soon after the morning observation, the larger part of it will generally reach the river by the next morning, and in such events no correction for rainfall should be made.

19. *Rapid rise at Dardanelle.*—When the river rises *rapidly* at Dardanelle it will not cause as high a stage at Little Rock as that indicated by the diagram. For a rise of 4 to 8 feet subtract about one-tenth of the rise at Dardanelle.

20. *Rapid fall at Dardanelle.*—When the river falls rapidly at Dardanelle it will not cause as low a stage at Little Rock as that indicated by the diagram by as much as about one-twentieth to one-tenth of the fall at Dardanelle, according to the rapidity of the fall.

21. *Cumulative corrections.*—When a rise sets in and it departs from the average relation as shown by the diagram, the departures are generally quite uniform, and the corrections necessary to be applied are quite accurately found by carrying forward from day to day the algebraic sum of the departure from the preceding forecast and all corrections applied for that forecast, except rainfall corrections. (Rules **14** to **18,** inclusive.) The rainfall at the two stations has largely produced its effect upon the stages at the lower station for which the forecast is being made by the end of the 24-hour period, and thus need not be considered on succeeding days. The sum of the corrections used as indicated above is designated the "cumulative" correction and will be so referred to in the examples following. As the river nears the crest stage the cumulative correction should be rapidly lessened.

22. *Falling river.*—The cumulative correction will be carried forward with a falling river. As the river falls to near flood stage a minus correction will generally lessen and as the river passes below flood stage the correction will generaltly change to a plus correction.

Figure 5 gives the average relation of the river stage at Fort Smith to the stage at Dardanelle 24 hours later. It will be noted that the extreme range for stages above 18 feet at Fort Smith is about the same as at Little Rock (fig. 6), but for stages at Fort Smith below 18 feet the range is greater. There are a few instances where the stage at Dardanelle was 8 feet, and in one instance it was 14 feet, above the average relation as shown by the figure. The latter stage was caused by torrential rains north of Fort Smith and Dardanelle, and the river

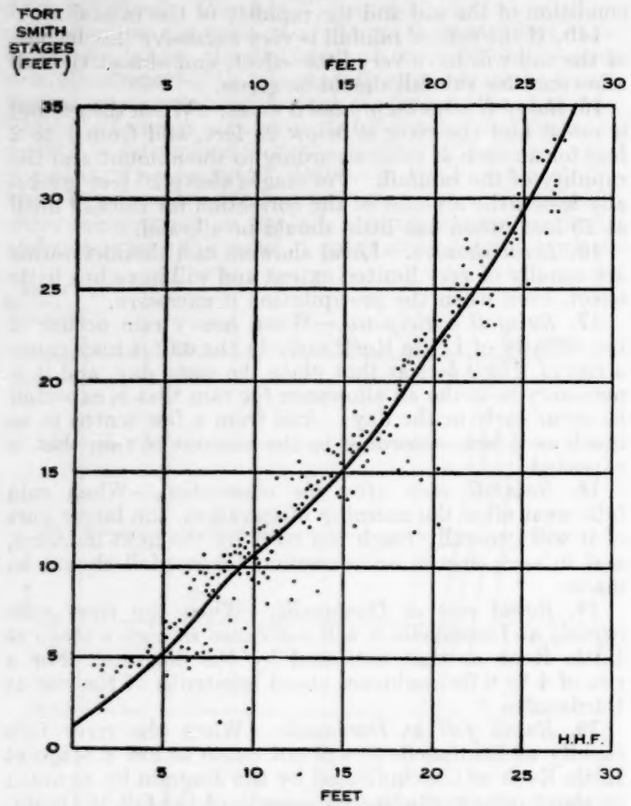


FIG. 5.—Graph showing the mean river stages at Fort Smith, Ark., and the corresponding stages at Dardanelle, Ark., 24 hours later.

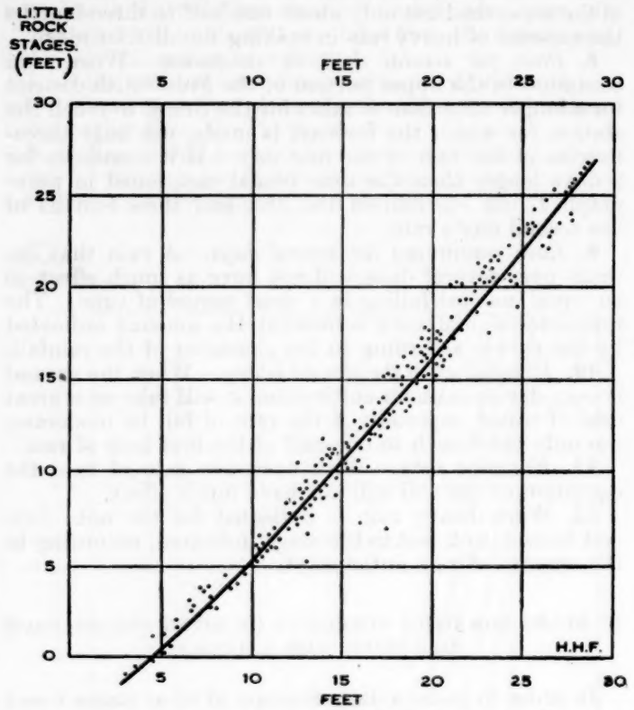


FIG. 7.—Graph showing the mean river stages at Little Rock, Ark., and the corresponding stages at Pine Bluff, Ark., 24 hours later.

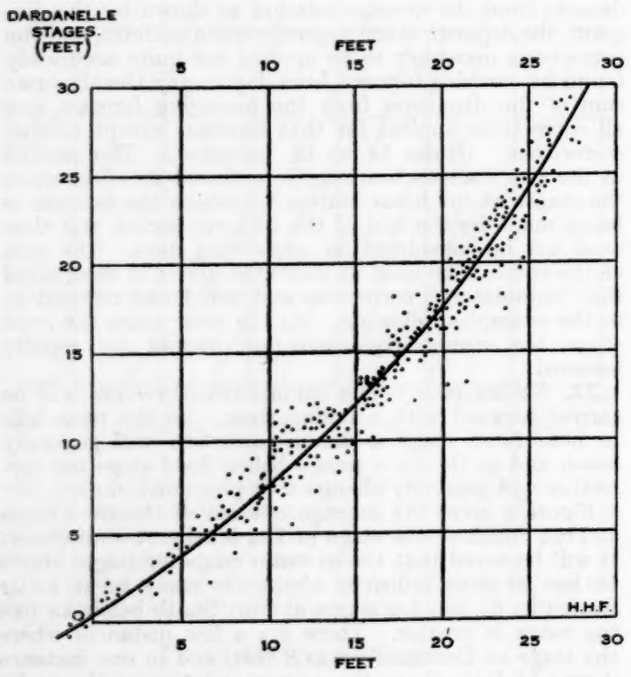


FIG. 6.—Graph showing the mean river stages at Dardanelle, Ark., and the corresponding stages at Little Rock, Ark., 24 hours later.

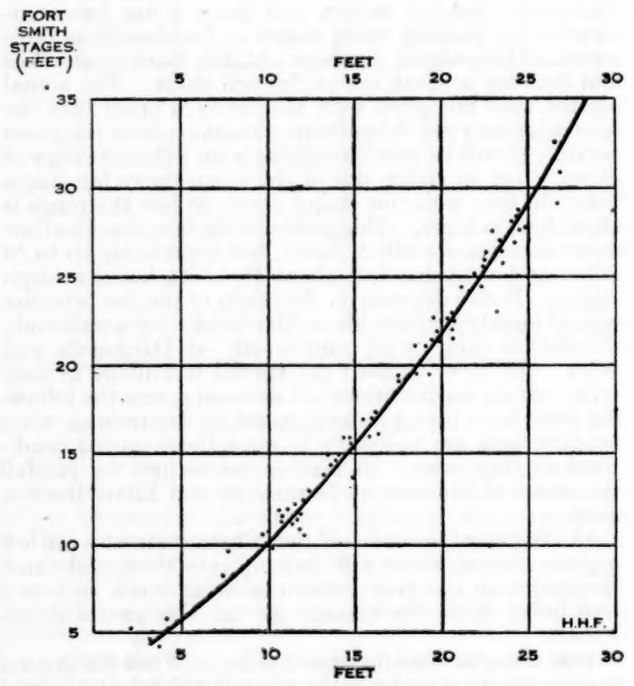


FIG. 8.—Graph showing the crest stages at Fort Smith, Ark., and the corresponding crest stages at Dardanelle, Ark., generally about one and one-half or two days later.

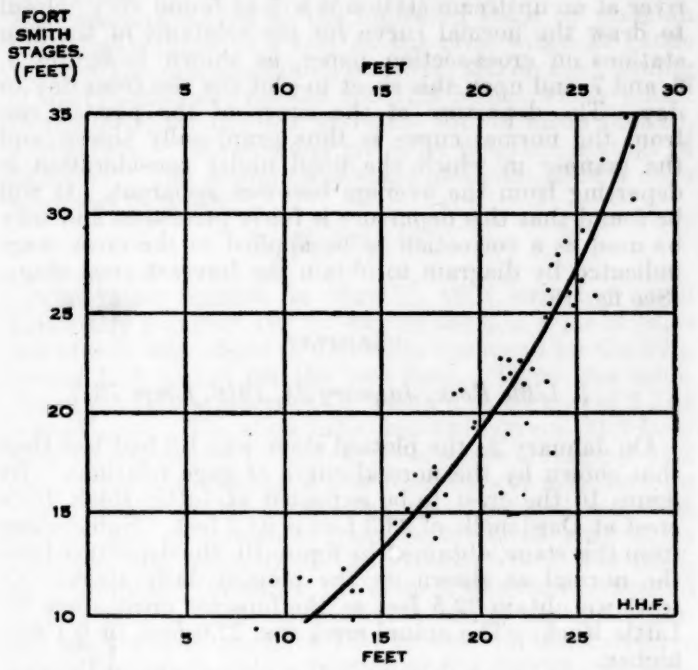


FIG. 9.—Graph showing the crest stages at Fort Smith, Ark., and the corresponding crest stages at Little Rock, Ark., generally about two days later.

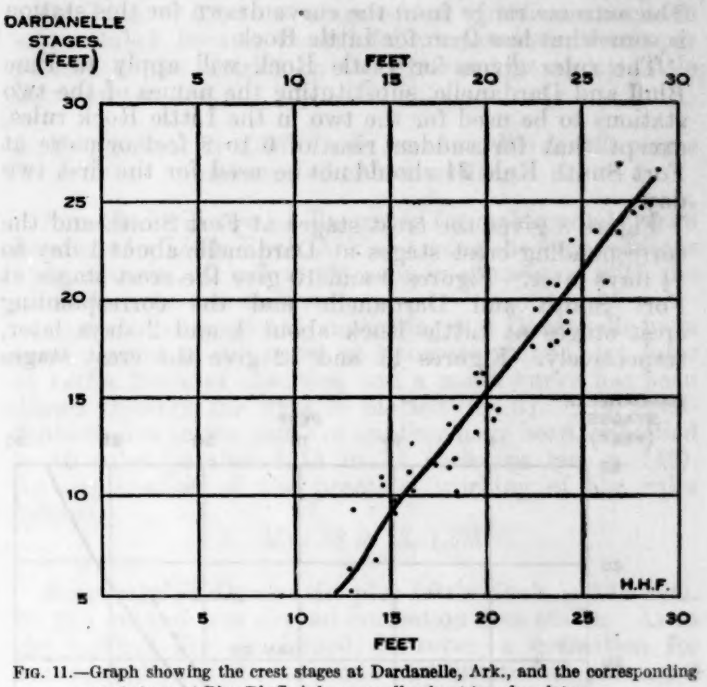


FIG. 11.—Graph showing the crest stages at Dardanelle, Ark., and the corresponding crest stages at Pine Bluff, Ark., generally about two days later.

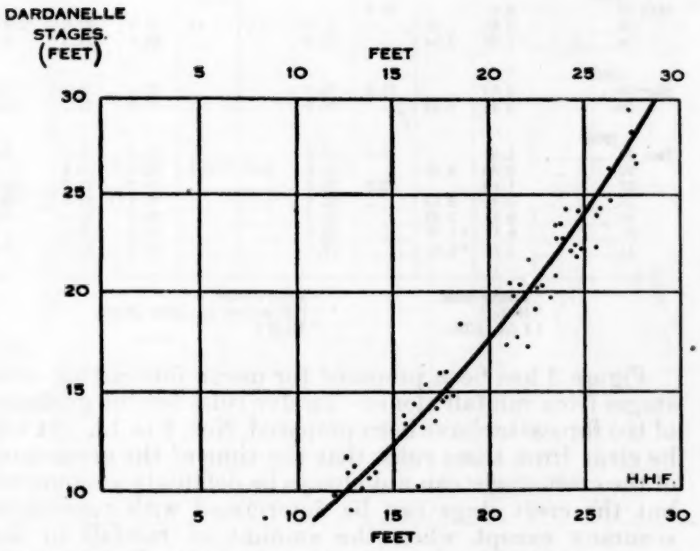


FIG. 10.—Graph showing the crest stages at Dardanelle, Ark., and the corresponding crest stages at Little Rock, Ark., generally one day later.

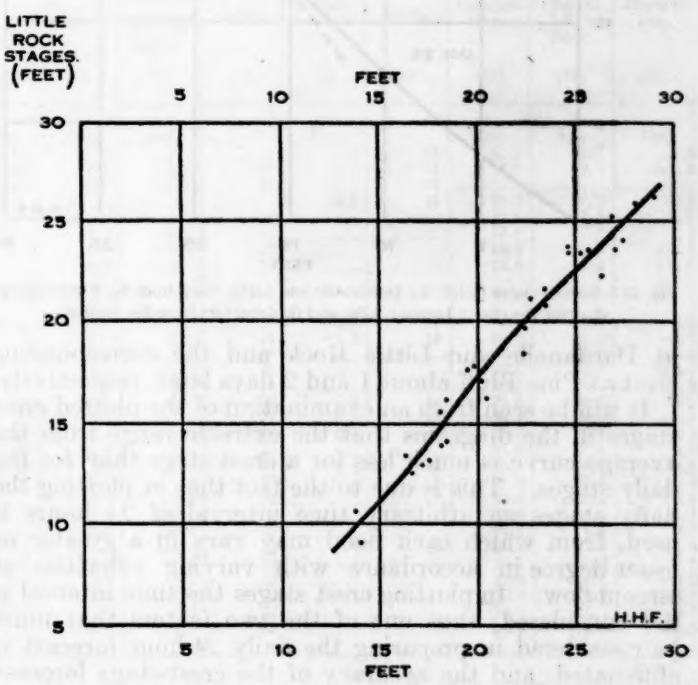


FIG. 12.—Graph showing the crest stages at Little Rock, Ark., and the corresponding crest stages at Pine Bluff, Ark., generally one day later.

rose simultaneously at both stations, the rise at Fort Smith being 17.4 feet and at Dardanelle 14.1 feet.

Figure 7 gives the average relations between the stages at Little Rock and Pine Bluff 24 hours later. The extreme range from the curve drawn for this station is somewhat less than for Little Rock.

The rules given for Little Rock will apply to Pine Bluff and Dardanelle, substituting the names of the two stations to be used for the two in the Little Rock rules, except that for sudden rises of 6 to 8 feet or more at Fort Smith Rule **21** should not be used for the first two days.

Figure 8 gives the crest stages at Fort Smith and the corresponding crest stages at Dardanelle about 1 day to 1½ days later. Figures 9 and 10 give the crest stages at Fort Smith and Dardanelle and the corresponding crest stages at Little Rock about 1 and 2 days later, respectively. Figures 11 and 12 give the crest stages

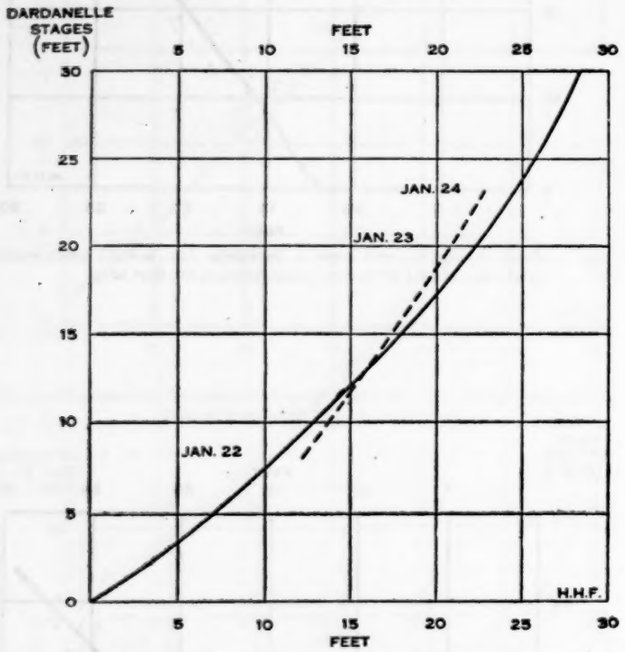


FIG. 13.—Normal curve (solid) for Dardanelle and Little Rock from fig. 6 and a graph showing the rise in January, 1916, and its departure from the normal.

at Dardanelle and Little Rock and the corresponding crest at Pine Bluff about 1 and 2 days later, respectively.

It will be seen from an examination of the plotted crest stages in the diagrams that the extreme range from the average curve is much less for a crest stage than for the daily stages. This is due to the fact that in plotting the daily stages an arbitrary time interval of 24 hours is used, from which each flood may vary in a greater or lesser degree in accordance with varying velocities of stream flow. In plotting crest stages the time interval is not considered; thus one of the two factors that must be considered in preparing the daily 24-hour forecast is eliminated, and the accuracy of the crest-stage forecast is thereby increased.

23. When the rain begins upstream and follows down the river, or when heavy rain occurs in the vicinity of the lower station so that it reaches the river on the arrival of the crest from upstream, add from 0.5 to 1.5 feet to the crest indicated by the curve.

24. When but little rain has fallen at both stations and heavy rain has fallen in the upper portion of the district, subtract a like amount.

25. In forecasting stages based upon the height of the river at an upstream station it will be found very helpful to draw the normal curve for the relations of the two stations on cross-section paper, as shown in figures 5, 6, and 7, and upon this sheet to plot the rise from day to day. The departure of the curve of the plotted rise from the normal curve is thus graphically shown and the manner in which the flood under consideration is departing from the average becomes apparent. It will be found that this departure is fairly presistent and may be used as a correction to be applied to the crest stage indicated by diagram to obtain the forecast crest stage. (See fig. 13.)

EXAMPLES.

1. Little Rock, January 24, 1916, figure 13.

On January 24 the plotted stage was 1.8 feet less than that shown by the normal curve of gage relations. By figure 10 the crest to be expected at Little Rock, for a crest at Dardanelle of 23.3 feet is 24.3 feet. Subtracting from this stage, obtained by figure 10, the departure from the normal as shown on the plotted daily stages (1.8 feet) we obtain 22.5 feet as the forecast crest stage for Little Rock. The actual crest was 22.6 feet, or 0.1 foot higher.

TABLE 2.—*Illustration of the use of figure 3 for forecasting crest stages at Little Rock, Ark.*

Date.	Mean rainfall.	Sum of rainfall.	Initial stage.	Stage by diagram.	Correction.	Rule.	Forecast stage.	Actual stage.	Departure.
1899.	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
May 6	2.00	.....	10.0	20.9	1.5	12	22.4	[1] 22.9	0.5
7	1.23	3.23	.....	24.6	.....	.....	24.6	[1] 24.5	−0.1
1908.									
May 22	0.31	.....	16.6	.....	.....	.....	.....	.....	.....
23	0.95	1.26	.....	21.3	2.0	12	23.3	[1] 23.6	0.3
24	[3] 1.28	2.54	.....	24.8	.....	.....	24.8	[1] 25.0	0.2
1908.									
May 29	0.68	.....	25.9	26.0	.....	.....	26.0	[3] 26.2	0.2
30	0.45	1.13	.....	26.4	.....	.....	26.4	26.2	−0.2
1916.									
Jan. 21	1.97	.....	8.0	20.2	.....	.....	20.2	[4] 21.0	0.8
22	0.30	2.27	.....	21.6	1.0	[5] 3	22.6	[4] 22.6	0
27	1.69	.....	22.0	24.2	.....	.....	24.2	[4] 24.0	−0.2
28	0.41	2.10	.....	25.4	.....	.....	25.4	[4] 25.3	−0.1
29	0.52	2.62	.....	26.2	.....	.....	26.2	[4] 26.3	0.1
30	0.52	[6] 2.71	.....	26.8	.....	.....	26.8	[4] 26.8	0
31	0.80	[6] 2.99	.....	27.1	.....	.....	27.1	[4] 27.3	0.2

[1] 4 days later.
[2] Rule 7.
[3] 1 day later.
[4] 2 days later.
[5] 1.25 inches at Little Rock.
[6] Rule 5.

Figure 3 has been prepared for use in forecasting crest stages from rainfall alone. Twelve rules for the guidance of the forecaster have been prepared, Nos. **1** to **12**. It will be clear from these rules that the time of the occurrence of the crest stages can not always be definitely announced, but the crest stage can be determined with reasonable accuracy except when the amount of rainfall in the ensuing 24 hours can not be accurately foreseen. In preparing the example submitted the writer had the advantage of a knowledge of the amount of rainfall in the ensuing 24 hours and therefore was able to fix the correction for anticipated rainfall with greater accuracy than would be possible in actual practice.

2. May 6, 1899.

Enter the diagram on the left with a mean rainfall of 2 inches and an initial stage of 10 feet. The correction for anticipated rainfall is placed at 1.5 feet (Rule **12**). This amount, added to the indicated stage by diagram (20.9 feet), gives 22.4 feet as the crest stage at Little Rock. The rain continued, however, and on the morning of the 7th the mean rainfall was 1.23 inches which, added to the mean for the 6th, gives the sum of mean rainfall, 3.23 inches. This amount gives, by diagram, a stage of 24.6 feet. The actual crest stage at Little Rock 4 days later was 24.5 feet.

3. May 22, 1908.

The mean rainfall on May 22, 1908, was too small materially to affect the rivers; on the 23d a mean rainfall of 0.95 was added to 0.31 inch, the mean for the 22d, giving 1.26 inches for the two days. There was additional rainfall in prospect for which a correction of 2 feet was allowed. The stage indicated by diagram (21.3 feet) plus the correction (2 feet) gives a forecast stage of 23.3 feet. Rain continuing, a new forecast was necessary on the morning of May 24. The mean rainfall was 1.98 inches, but as excessive rain occurred at only three stations, only one-half of the excessive rain was used, and the mean rainfall for the district was thus computed as 1.28 inches. Adding this to the sum of the mean rainfall for the 23d, we have 2.54 inches. When excessive rainfall occurs in only a portion of the district, the forecaster must determine whether to use 0.5, 0.6, 0.7, or 0.8 of the excessive amounts, according to the percentage of the district over which heavy or excessive rain occurs. The indicated stage by diagram, for 2.54 inches, with the initial stage of 16.6 feet, is 24.8 feet. The actual stage 4 days later was 25 feet, or 0.2 foot higher. The record for May 29 and 30, 1908, is given (see Table 2) to illustrate a case where the rainfall was moderate and the river was already at a high stage; hence no correction for rainfall was deemed necessary.

4. January 22, 1916.

On January 22, 1916, a correction of 1 foot was made under Rule **5**, because the rainfall was heavy in the upper portion of the district on the 21st and heavy at Little Rock on the 22d.

Daily forecasts for Little Rock, based on Dardanelle stages and rainfall at both stations.

A method will now be illustrated for making daily stage forecasts for Little Rock, Ark., by using the gage readings at Dardanelle, 87 miles upstream, in connection with the rainfall at the two stations.

As stated on page 145, rising stages at Dardanelle have been plotted as ordinates and the stages one day later at Little Rock as abscissæ, and a mean curve has been drawn through the data so plotted (fig. 3). The modifications due to one cause or another have been embodied in 10 rules numbered **13** to **22**, inclusive (see p. 145). An explanation of the practical working of the rules follows.

5. May 12 to 18, 1905.

Mean rainfall, Dardanelle plus Little Rock, is 0.16 inch. As the ground was dry no correction was made. As in the method first explained, however, a correction for anticipated rainfall was made and entered in column 9 as 1 foot.

TABLE 3.—*Illustrating daily river forecasts at Little Rock, Ark., by means of the gage heights at Dardenelle and the rainfall at both stations (fig. 6).*

Date.	Dardanelle stage.	Rainfall— Fort Smith.	Rainfall— Dardanelle.	Rainfall— Little Rock.	Stage by Fig. 6.	Cumulation corrections, Rules 21 and 22.	Rule.	Correction.	Rule.	Forecast stage.	Actual stage at Little Rock.	Departure.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1905.	*Feet.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*	*Feet.*
May 12	9.5	0.02	0.12	0.21	12.2			1.0	17	13.2	13.7	0.5
13	9.6	0.91	3.20	3.56	12.3	0.5	21	1.7	14	14.5	13.8	−0.7
14	13.7	0.32	0.20	0.22	16.7	−0.2	21	−0.4	19			
14								0.2	15	16.3	16.5	0.2
15	15.0				18.0	−0.4	21			17.6	17.8	0.2
16	14.5				17.3	−0.2	22			17.1	17.2	0.1
17	13.7				16.7	−0.1	22			16.6	16.3	−0.3
18	12.7				15.7	−0.4	22			15.3	15.4	0.1
1916.												
Jan. 22	8.2	0.05	0.54	1.25	10.4			1.8	15	12.2	12.5	0.3
23	20.3				22.4	0.3	21	−1.2	19	21.5	21.0	−0.5
24	23.1				24.5	−1.4	21			23.1	22.6	−0.5
25	23.2				24.6	−1.9	21			22.7	22.6	−0.1
26	22.3				24.0	−2.0	21			22.0	22.0	0
27	21.9	2.68	1.25	0.80	23.7	−2.0	22	0.8	14	22.5	22.6	0.1
28	25.2	0.26	0.80	1.19	25.8	−1.9	21	0.5	15	24.4	24.0	−0.4
29	27.5	0.11	0.75	1.44	27.4	−2.3	21	0.3	15	25.4	25.3	−0.1
30	29.0	1.50		0.02	28.0	−2.4	21			25.6	26.3	0.7
31	29.4	0.56	1.40	1.22	28.0	−1.7	21	0.4	15	26.7	26.8	0.1
Feb. 1	29.5			0.33	28.1	−1.6	21			26.5	27.3	0.8
2	28.8				27.7	−0.8	22			26.9	27.2	0.3
3	27.2				27.0	−0.5	22			26.5	26.3	−0.2
4	24.0	0.55			25.0	−0.7	22			24.3	24.4	0.1
5	18.5				21.0	−0.6	22	0.6	20	21.0	22.0	1.0
6	15.5			0.44	18.4	0.4	22	0.3	20	19.1	20.0	0.9
7	14.1				17.0	1.3	22			18.3	18.1	−0.2
8	13.0				15.8	1.1	22			16.9	16.8	−0.1
9	12.1	0.01		0.03	15.0	1.0	22			16.0	15.5	−0.5
10	11.4				14.3	0.5	22			14.8	14.3	−0.5

The indicated stage for Little Rock by diagram is 12.2 feet. To this is added 1 foot, as provided under Rule **17**, and the result is 13.2 feet, the forecast stage for Little Rock on May 13. The actual stage at that station was 13.7 feet, or 0.5 foot higher than the forecast stage.

May 13, 1905.—As explained in Rule **21**, the "cumulative" correction, the algebraic sum of the departure

from the preceding forecast and the corrections by Rules **13** and **19** to **22**, inclusive, is carried forward each day. The mean rainfall, Dardanelle plus Little Rock divided by 2, is 3.38 inches. As the ground was relatively dry and the rainfall at Fort Smith was only 0.91 inch, the lowest rate or 0.5 foot rise for each inch of rain is assigned (Rule **14**), which gives 1.7 feet (see Table 3, column 9). Adding the cumulative correction, +0.5 foot, gives 0.5+1.7=2.2 feet, the total correction to be applied to the stage indicated by the diagram figure 6, and 12.3+2.2=14.5 feet is the forecast stage for the 14th. The actual stage was 13.8 feet or 0.7 foot below the forecast stage.

May 14, 1905.—The cumulative correction, as before, is obtained by combining the corrections for the 13th in columns 7 and 13 (Table 3). As previously explained, the correction in column 9, being for rainfall, is omitted. Thus, −0.7+0.5=−0.2 is the cumulative correction to be carried forward. As the river rose rapidly (4.1 feet) at Dardanelle, one-tenth of this amount is entered as a minus correction in column 9 (Rule **19**). A rainfall correction of +0.2 is also entered in column 9 (Rule **15**). We have then −0.2, −0.4, and +0.2, or a total correction of −0.4 foot.

The stage indicated by figure 6, was 16.7 feet; subtracting the correction of −0.5 leaves 16.3 feet, the forecast stage for the 15th. The actual stage was 16.5 feet, or 0.2 foot higher.

May 15, 1905.—To get the cumulative correction for this date we take, as before, all of the corrections for the 13th except the rainfall correction. Thus (adding) −0.2, −0.4, and +0.2=−0.4.

The stage indicated by figure 6 is 18 feet. As there are no other corrections to be applied, we have 18.0−0.4=17.6 feet, the forecast stage for the 16th. The actual stage was 0.2 foot higher.

May 16, 1905.—Proceeding as before, we have (adding) +0.2, −0.4=−0.2 as the cumulative correction. That amount, deducted from the stage indicated by diagram, 17.3 feet, gives 17.1 feet as the forecast stage for the 17th. The actual stage was 0.1 foot higher.

May 17, 1905.—Combining as before, +0.1 and −0.2 equals −0.1 foot, the cumulative correction. Substracting this amount from the indicated stage, 16.7 feet, we have 16.6 feet as the forecast stage for the 18th. The actual stage was 16.3 feet, or 0.3 foot lower.

May 18, 1905.—The cumulative correction is −0.3+−0.1=−0.4. Subtracting this amount from the indicated stage, 15.7 feet, gives 15.3 feet as the forecast stage for the 19th. The actual stage was 15.4 feet, or 0.1 foot higher.

6. January 27 to 29, 1916.

The following examples show the lessening effect of rainfall on high stages of the river:

January 27, 1916.—A cumulative correction of −2 feet is brought forward from the 26th. As the river was high, but 0.8 foot rise was allowed for each inch of rainfall (Rule **15**). Adding −2.0+0.8=−1.2 feet, the correction to the indicated stage. The stage indicated by diagram (fig. 6) was 23.7 feet. Hence 23.7−1.2=22.5 feet, the forecast stage for the 28th. The actual stage was 0.1 foot higher.

January 28, 1916.—Combining as before, we have a cumulative correction of −1.9 feet. As the river was high, but 0.5 foot was allowed for each inch of rainfall, which gives −1.4 as the total correction. This, subtracted from the indicated stage (25.8 feet), gives 24.4 feet as the forecast stage. The actual stage was 0.4 foot lower.

January 29, 1916.—Combining as before, we obtain a cumulative correction of −2.3 feet. As the river was very high, but 0.3 foot rise was allowed for each inch of rain. Adding: −2.3 and +0.3=−2.0 as the total correction, which, applied to the indicated stage, 27.4 feet, gives 25.4 feet as the forecast stage. The actual stage was 0.1 foot lower.

THE DISAPPEARANCE OF SNOW IN THE HIGH SIERRA NEVADA OF CALIFORNIA.

By ALFRED J. HENRY, Professor of Meteorology.

[Dated: Weather Bureau, Washington, Apr. 15, 1916.]

Much effort has been put forth in many parts of the world, to determine the depth and distribution of precipitation in the form of snow, yet but little attention seems to have been given to the conditions attending the disappearance of snow. The ordinary conception that the snows of winter are melted by the increased insolation of late spring and early summer seems to be sufficiently close to the truth to satisfy the average inquirer.

The object of this paper is to determine whether the available records of snowfall made by cooperative observers, afford any insight into the weather conditions which may modify or control the disappearance of snow. The subject is, moreover, rather closely associated in the public mind with flood causation. Time was when the June floods in the Missouri River were considered as being due to the melting of winter snowfall at the headwater streams, but that impression is fast disappearing in the light of modern records of precipitation and streamflow for the headwaters of that stream. Floods in the rivers of New England and the tier of northern states extending thence westward to the Dakotas, are intensified by the snow cover which may be on the ground toward the end of spring. The release of the snow water, however, is not easily accomplished except the night temperatures be continuously above freezing for several consecutive days—a rather unusual condition in spring. Hence snow floods are rare even in the more northern rivers of the United States. In Washington and Oregon, due to the proximity of those states to the Pacific Ocean, warm winter rains sometimes fall upon a deep snow cover and floods result, but even in those states snow-melting weather during the winter and late spring is of infrequent occurrence. The most pronounced snow flood of the United States is that which annually passes down the Columbia River, due almost wholly to the melting of the snow cover at the higher altitudes of its drainage basin. The depth of the snow cover is usually fairly well known from observations made by snowfall observers of the Weather Bureau, supplemented by reports from cooperative observers, but the manner in which the snow cover will disappear, whether by slow melting and rapid evaporation or by rapid melting and quick runoff, can not be determined with any certainty far in advance.

In a study of this subject one naturally turns to the high Sierra of California, where a great amount of snow falls during winter and its disappearance during spring can be carefully observed. Reports of snowfall are available for a number of stations in that region, but we have confined our attention to three stations whose altitudes and geographical coordinates are shown below in Table 1.

TABLE 1.—*Location of mountain snowfall stations.*

Station.	Altitude.	Latitude (N.).	Longitude (W.).	Topography.
	Feet.	° ′	° ′	
Fordyce Dam, Cal.	6,500	39 23	120 29	West slope Sierra Nevada.
Summit, Cal.	7,017	39 19	120 20	Summit of Divide.
Tamarack, Cal.	8,000	38 30	119 50	West slope Sierra Nevada.

The two stations first named are representative of the snow conditions along and near the line of transcontinental railway where it crosses the Sierra Nevada in California.

The drainage of Fordyce Dam is westward into the Yuba River, a tributary of the Sacramento; the drainage of the Summit station, on the contrary, is eastward into the Truckee River. The third station is in Alpine County, in the slight depression in which the Blue Lakes are situated and a quarter of a mile south of lower Blue Lake. The drainage is to the northwestward into the Mokelumne, a tributary of the San Joaquin River. This station is also quite near the Carson watershed and is typical of the high Sierra to the southwest of Lake Tahoe. Mountain masses 500 to 1,000 feet higher abound on the west and also to the northeast of the station.

We have summarized from the snowfall reports published in "Climatological Data—California Section," and from the manuscript data kindly supplied by Section Director George H. Willson, the facts shown in Table 2, below.

TABLE 2.—*Disappearance of snow in the Sierra Nevada of Central California, February–April.*

Fordyce Dam, Cal.

Year.	February.	March.	April.	Total.	Date of final disappearance.	Average daily disappearance.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*
1908	36	94	32	162	June 22	1.8
1909	92	98	43	233	July 1	1.8
1910	51	51	37	139	May 26	1.6
1911	83	120	76	279	July 12	3.1
1912	18	49	65	132	June 21	1.4
1913	17	51	61	129	June 11	1.4
1914	60	39	54	153	June 20	1.7
1915	116	55	49	220	June 26	2.5
Mean	59	69	52	180	June 21	1.9

Summit, Cal.

1907	86	91	167	344	July 14	3.9
1908	58	116	51	225	June 11	2.5
1909	41	68	71	180	June 21	2.0
1910	47	46	63	156	June 6	1.8
1911	56	76	90	222	June 13	2.5
1912	21	31	56	108	June 13	1.2
1913	53	37	45	135	May 31	1.5
1914	75	64	58	197	June 9	2.0
1915	61	81	76	218	June 6	2.4
Mean[1]	51	65	64	180	June 11	2.0

Tamarack, Cal.

1907	113	63	167	343	July 27	3.9
1908	59	95	38	192	June 7	2.1
1909	51	44	55	150	July 1	1.7
1910	51	42	45	138	June 3	1.6
1911	12	169	213	394	July 8	4.4
1912	19	41	72	132	June 24	1.5
1913	32	33	50	115	June 12	1.3
1914	42	39	32	113	June 20	1.3
1915	51	62	54	167	June 26	1.9
Mean[1]	40	65	70	175	June 20	2.0

[1] For the period 1908–1915.

The depth of snow which disappeared during the months of February, March, and April is easily obtained by considering the depth of snow on the ground at the beginning of the month as the initial point, adding thereto the fall during the month and comparing the sum thus obtained with the depth on the ground at the end of the month. The depths in Table 2 were thus obtained and these figures represent the amount of snow that disappeared from whatever cause during the month. As might be expected, the daily rate of disappearance varies according to the weather conditions, ranging from a little more than an inch to as much as four inches per day, and a greater amount for short periods. The total amount of snow that disappears during the months February to April, inclusive, on the average, of all conditions, at the three stations, is shown in the small table below.

TABLE 3.—*Disappearance of snow by months.*

Station.	Month.			
	February.	March.	April.	Total.
	Inches.	*Inches.*	*Inches.*	*Inches.*
Fordyce Dam	59	69	52	180
Summit	51	64	64	180
Tamarack	40	65	70	175

The very close agreement in the average values for so short a period is evidence that they represent a real phenomenon. The variations from the mean values may be seen from the detailed amounts for each season, as given in Table 2. Thus in 1907, notably in the month of April, the weather was particularly effective in causing a rapid disappearance of snow, but the greatest amount of snow to disappear during any one year within the period of observations was in 1911, in the months of March and April. The weather conditions during February, March, and April, 1907, may be summarized as follows: February, a warm month with not much precipitation; March, a wet month with heavy precipitation, mostly in the form of snow at the higher levels, with temperatures mostly below freezing at Summit and Tamarack; April a warm and relatively dry month, with plenty of sunshine in the last half of the month. The weather of 1911 may also be summarized as follows: February, a cold month with much cloudy weather and frequent precipitation; March, a little warmer than the average, a large amount of precipitation, and a period of about 20 consecutive days of dry, warm weather, during which snow disappeared very rapidly as will be later pointed out; April, cold and cloudy in the beginning but after the first decade there was a period of clear, dry weather, during which the snow melted at the uniform rate of about 4 inches daily.

A significant circumstance in connection with the very large disappearance of snow in 1907 is the fact that the Truckee River which drains the region about Summit reached and maintained higher stages than the average from March to November of that year, thus indicating the absorption by the ground of a large amount of snow water which later found its way into the river. The effect on the rivers of the second season of high melting 1911, was not apparent beyond July of that year.

The seasons of small melting were as follows: 1910, 1912, 1913, and, for Tamarack, 1914, in addition to the 3 years first named. The weather conditions during 1910 were as follows: February, cold and dry without warm

rains; March, warm and dry with steady decrease in snow cover during first 20 days; April, warm and dry light snowfall and much sunshine, snow melting rapidly.

1912. February, a very dry month with warm sunshiny days. No snow during last half of month; March cool and rainy; April, very cold with somewhat more precipitation than the average. Very little packed snow at high altitudes, owing to the deficiency during January and February.

1913. February, cold and dry with light snowfall in the mountains; March, cool and dry, no warm spells and a shortage in snow; April, cool and dry, light snowfall in the mountains.

In setting forth the weather conditions associated with snow melting we are impressed with the fact that years with little snow melting are primarily years of greatly diminished fall, coupled with low temperature, and that years of great melting are years with heavy precipitation and relatively high temperatures. It would also seem that the opportunities for melting are as great if not greater during years of little snow as during years of much snow. The air temperatures and probably the wind seem to be the prime factors in the disappearance of snow, although doubtless there are other important causes. February, 1912, was a month during which but a small amount of snow disappeared; the weather was very dry in the sense that precipitation was light and infrequent and the total snowfall at the mountain stations was much less than the quantity which disappeared. The temperature was slightly above the average and the sunshine was fairly abundant, conditions which would seem to be favorable to rapid evaporation and melting, yet the amount which disappeared at the three stations considered, was far below the average. The depth on ground on January 31, 1912, and the amount that disappeared at the three stations considered was:

Station.	Depth on ground.	Disappeared.
	Inches.	*Inches.*
Fordyce Dam	59	18
Summit	41	21
Tamarack	55	19

The individual records of the three stations during snowless periods of varying length were examined, with the result that it appears that the weather in the high Sierra Nevada of California during a dry period is mostly dominated by high atmospheric pressure with little or no wind; the temperature rises above freezing in daytime and sinks below at night.

There is no apparent relation between small changes in temperature, either positive (upward) or negative (downward) and the rapid or slow melting of snow, nor does the disappearance of snow seem to be conditioned upon the day temperatures being above 32°F. The daily mean temperature is constantly oscillating up and down through a range of 1 to 10 degrees; these short-period changes do not appear to noticeably influence the melting of the snow cover even when the daily mean temperature passes above 32°F. and remains above for three or four consecutive days. After the first of February the majority of the short-period changes are positive, but their duration is short until the warm season is well advanced.

The weather conditions during a typical snowless period at Fordyce Dam, Cal., are given in the Table 4, below, for the month of February, 1912.

TABLE 4.—*Meteorological record for February, 1912, at Fordyce Dam, Placer County, Cal.*

[By E. E. Roenig, cooperative observer.]

Date.	Temperature.			Precipitation.			Prevailing wind direction.	Character of day, sunrise to sunset.
	Maximum.	Minimum.	Mean.	Amount.	Snowfall, in inches.	Depth of snow on ground at time of observation.		
	°F.	°F.	°F.	*Inches.*		*Inches.*		
1	35	22	28			59.0	sw.	Clear.
2	51	19	35			58.0	sw.	Clear.
3	45	13	29			58.0	sw.	Clear.
4	53	19	36			57.0	sw.	P't cl'dy.
5	45	27	36			56.0	sw.	Clear.
6	49	22	25			55.0	sw.	P't cl'dy.
7	43	23	33	0.04		54.0	sw.	P't cl'dy.
8	49	35	42			53.0	sw.	P't cl'dy.
9	46	35	40	0.10		52.0	sw.	P't cl'dy.
10	41	33	37			51.0	sw.	P't cl'dy.
11	43	26	34			51.0	ne.	Clear.
12	50	24	37			50.0	sw.	P't cl'dy.
13	45	32	38	T.		50.0	sw.	Cloudy.
14	46	38	42	0.35	3.0	52.0	sw.	Cloudy.
15	49	26	37			52.0	sw.	P't cl'dy.
16	50	34	42			51.0	sw.	P't cl'dy.
17	43	38	40	0.95		50.0	sw.	P't cl'dy.
18	47	39	43	0.35		49.0	sw.	P't cl'dy.
19	39	32	35			49.0	ne.	Clear.
20	47	25	36			48.0	ne.	P't cl'dy.
21	32	27	30			48.0	ne.	Clear.
22	46	26	36	T.		47.0	sw.	P't cl'dy.
23	31	27	29	T.		47.0	ne.	P't cl'dy.
24	29	24	26			46.0	ne.	P't cl'dy.
25	41	26	34			46.0	nw.	Clear.
26	49	20	34			46.0	nw.	P't cl'dy.
27	48	23	35			45.0	s.	Clear.
28	57	30	40			45.0	sw.	Clear.
29	50	28	39			44.0	sw.	Clear.
Mean	45.6	27.7	.....	1.79	3.0	.....	sw.	

Rapid disappearance of snow.—In studying the records of rapid disappearance of snow, it was found, as might have been expected, that freshly fallen snow disappeared much more rapidly than a cover of old snow that had been well packed by the wind and by alternate melting and freezing, and this is believed to be the explanation of the fact that years of greatest snowfall are also years of most rapid disappearance of snow.

The depth of snow may diminish (1) by melting and ground absorption when the ground is not frozen; (2) by settling or packing under the influence of high winds; (3) by evaporation. It is a matter of common observation that fresh snow packs or settles upon exposure for a few days to the weather. The following examples will perhaps make the application of the above clearer:

Example No. 1: On February 27, 1908, at Fordyce Dam snow began to fall, with a layer of 79 inches already on the ground. It snowed continuously for 9 lays, during which a total of 95 inches was recorded. This amount, added to the old cover, increased the latter by 43 inches only, or less than 50 per cent of its full value. Immediately after the snow ceased falling the daily disappearance for a period of 6 days was on the average 4.6 inches per day. The mean temperature for the same period was 23°, but the mean maximum was 46°.

Example No. 2: At Summit, Cal., from March 1 to 10, 1911, a total of 99 inches of snow fell; then followed a period of 25 consecutive days without precipitation and with day temperatures above freezing and night temperatures slightly below. The depth of the snow cover at the beginning was 215 inches. At the end of the snowfall period it was 307 inches. Immediately the snow ceased falling it began to disappear very rapidly; there was a period of 9 consecutive days from March 16 to 24, when the average daily rate of decrease was at a maximum, viz, 11.4 inches. For the entire period

of 25 days the average rate of diminution was 7.4 inches daily. During the time of maximum decrease the mean temperature was 36°, the mean maximum was 43°, mean minimum 29.7°. The weather was mostly clear with southwest and south winds.

The practical application of the foregoing seems to be that whatever the amount of snow on the ground in midwinter a considerable portion of it will disappear through natural causes aside from the occurrence of warm weather attended by rain. The depth that disappears, on the average, expressed in percentages of the amount on the ground on the first of the month, is as follows:

TABLE 5.—*Percentage of disappearance of snow.*

Station.	February.	March.	April.
	Per cent.	*Per cent.*	*Per cent.*
Fordyce Dam	67	70	51
Summit	45	54	42
Tamarack	29	36	42

These figures show that altitude is a function in the disappearance of snow, the greater the altitude the slower the melting, as is perfectly obvious. The stations at Fordyce Dam and Summit show a greater melting in March than in April, contrary to the showing for Tamarack, and the natural expectation that the rate of melting would increase with the advance of the season.

Conclusions.—The most favorable weather conditions for the conservation of a snow cover are low temperature and little wind movement. The average loss by evaporation under these conditions appears to be about three-quarters of an inch per day.

Unfavorable weather conditions are relatively high temperature, brisk wind movement, and plenty of strong sunshine. Under the most unfavorable conditions for the conservation of snow the loss of freshly fallen snow may average 10 inches per day and of old snow from 3 to 4 inches.

BIBLIOGRAPHY.

Le Conte, J. L. Snowfall in the Sierra Nevada, Sierra Club Bulletin, 1908, Vol. **6,** pp. 310–14.

McAdie, Alex. G. Snowfall Records at Summit, MONTHLY WEATHER REVIEW, **38:** 940.

Forecasting the Supply of Water for the Summer from the Depth of Snow. Ibid. **39:** 445.

Forecasting the Water Supply of California. Ibid. **41:** 1092–3.

Palmer, Andrew H. The Region of Greatest Snowfall in the United States, MONTHLY WEATHER REVIEW, **43:** 217.

CORRIGENDA.

January REVIEW, 1916:

Page 35, Table 16. The daily amounts of rainfall at San Diego, Cal., January, 1916, should read:

	Amount.
Jan. 16	0.95
17	1.55
18	0.31
19	0.80
20	0.00
Total	3.61
Jan. 24	T.
25	0.21
26	0.22
27	2.19
28	0.06
29	0.17
Total	2.85

Page 35, Table 14. Daily precipitation at Mill Creek, *for* the leaders under January 16, 17, 18, and 27, 28, *read* an asterisk (*).

SECTION V.—SEISMOLOGY.

THE SOUTHERN APPALACHIAN EARTHQUAKE OF FEBRUARY 21, 1916.

By W. J. HUMPHREYS, Professor in charge of Seismological Investigations.

[Dated: Weather Bureau, Washington, D. C., Apr. 26, 1916.]

On February 21, 1916, about 6:40 p. m., 75th M. time, an earthquake occurred in the Appalachian Mountains of western North Carolina that was distinctly felt not only in various parts of that State but also in South Carolina, Georgia, Alabama, Tennessee, Kentucky, Virginia, and, presumably, in West Virginia. The various places from which reports of this quake were received and the corresponding intensities, as estimated by the observers, are given on the accompanying chart. Most of these reports were published in detail in the REVIEW for February, 1916.

The last earthquake of note that occurred in this general region was on January 1, 1913,[1] with the epicenter near Union, S. C. While this earthquake had a higher intensity than the one under discussion, yet the area affected was only approximately one-fifth as great. On October 29, 1915, an earthquake with an intensity of IV, Rossi-Forel, was felt in Buncombe County, N. C., the same county in which the one of February 21 was the most severe, but reported only from Asheville and its immediate vicinity. Earthquakes are not uncommon in the southern Applachians; indeed, scarcely a year passes without one or more being felt somewhere in this region.

According to scattered reports the epicenter of the earthquake of February 21 was near Skyland, N. C., lat. 35° 30′ N., long. 82° 30′ W., where an intensity of VI, Rossi-Forel, was reported. The area over which this quake was felt, elliptical in shape, with the longer axis in a NE.-SW. direction, exceeded 200,000 square miles. The most distant point from the epicenter (assumed to be at Skyland, N. C.), to report feeling the shock is Norfolk, Va., 365 miles away. Instrumentally the quake was recorded at Harvard University, 1,250 miles away; Canisius College, Buffalo; University of Kansas, Lawrence; St. Louis University, St. Louis; Georgetown University, and the Weather Bureau, Washington, D. C.

The time of the disturbance, as given by a majority of the observers, whose reports show a surprisingly close agreement, was approximately 6:40 p. m., eastern time. Mr. M. L. Church, of Marshall, N. C., about 25 miles from the epicenter, gives the time of ending as $6^h\ 39^m\ 45^s$, and from his estimated duration places the beginning at $6^h\ 39^m\ 15–30^s$. These values are quite reliable, as the error of Mr. Church's watch was obtained by telegraph within five minutes after the disturbance. The times of beginning at the epicenter, as determined respectively from the seismograph records of Harvard University, Georgetown University, and the Weather Bureau by means of the P–O and S–O tables of Dr. Klotz, were substantially the same and averaged $6^h\ 39^m\ 17^s$.

Of course, consistent reports as to intensity could not be expected, owing to occupation of observer, nature and intensity of artificial disturbances, errors of estimation, and many other factors. Hence the isoseismals on the accompanying chart are only relative and drawn to the average values of intensity.

Sounds were quite uniformly reported within the territory bounded by the IV isoseismal. Within a radius of 200 miles from the epicenter, approximately that of the III isoseismal, rattling of dishes and windows was noted. Several stated that it was the most severe quake they had experienced since the Charleston earthquake of August 31, 1886. Crockery and other utensils fell from shelves in several cities. Near Sevierville, Tenn., a team of horses became frightened and ran away, tearing up a buggy, while in the town bricks were shaken from chimneys. Near the same place, in Wears Valley, several springs increased in volume, some running muddy—a common earthquake phenomenon. A few observers reported the cracking of plaster. People became alarmed at several places within the territory bounded by the V isoseismal and rushed from their homes, but no damage of consequence occurred anywhere.

The data used in this note were assembled by Mr. R. H. Finch, who deserves much credit for his careful attention to the details of the seismological reports.

[1] *Taber, Stephen*, in Bull. Seis. Soc. Amer., March, 1913, 3, No. 2, pp. 6–13.

AN EARTHQUAKE OBSERVED WITH A TELESCOPE.

Mr. Wendell P. Hoge, of the Mount Wilson Solar Observatory, observed the earthquake of March 22 (see below, Table 1, California), in an interesting and unusual way. The following is from a card report rendered by Mr. Hoge:

> This disturbance noticed while watching star image in 60-inch telescope, using high-power eyepiece. Oscillations of star image in the field rapid and short at first, becoming more marked in the middle and diminishing at the end of the disturbance. Evidently a very faint shock. Mr. G. A. Monk, using the instrument a little later at 4:50 and at 4:56 a. m., noticed two very feeble oscillations.

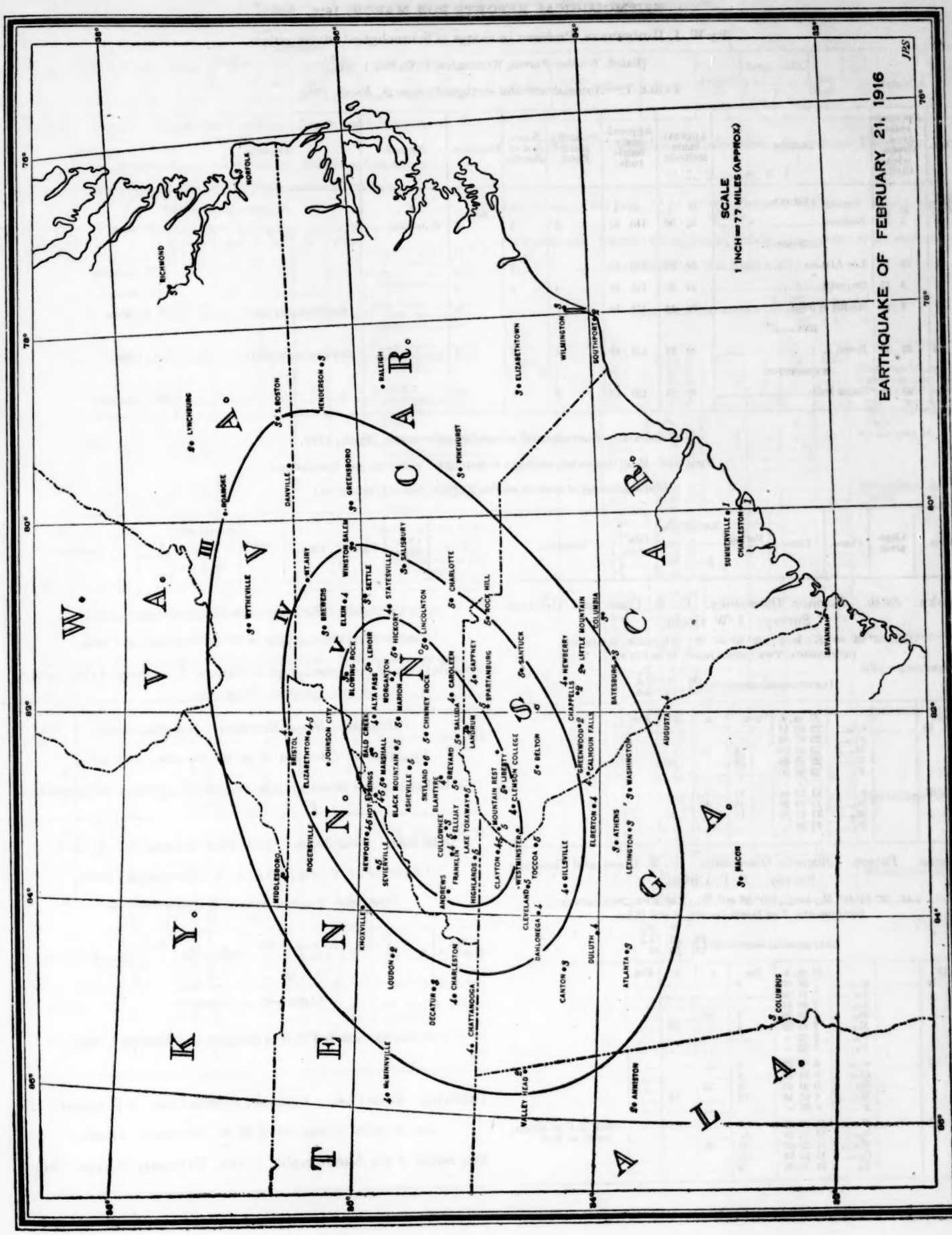

EARTHQUAKE OF FEBRUARY 21, 1916
SCALE
1 INCH = 77 MILES (APPROX)
W. VA.
KY.
TENN.
N. CAR.
S. CAR.
GA.
ALA.
RICHMOND
NORFOLK
LYNCHBURG
ROANOKE
S. BOSTON
DANVILLE
HENDERSON
GREENSBORO
RALEIGH
PINEHURST
ELIZABETHTOWN
WILMINGTON
SOUTHPORT
SUMMERVILLE
CHARLESTON
WYTHEVILLE
ST. AIRY
WINSTON SALEM
SETTLE
STATESVILLE
SALISBURY
CHARLOTTE
ROCK HILL
BREWERS
ELKIN
BLOWING ROCK
LENOIR
ALTA PASS
MORGANTON
HICKORY
MARION
LINCOLNTON
BRISTOL
ELIZABETHTON
JOHNSON CITY
BALD CREEK
SALUDA
CAROLEEN
GAFFNEY
SPARTANBURG
SANTUCK
ROGERSVILLE
NEWPORT
HOT SPRINGS
MARSHALL
BLACK MOUNTAIN
ASHEVILLE
CHIMNEY ROCK
SKYLAND
BREVARD
LANGRUM
MIDDLESBORO
KNOXVILLE
SEVIERVILLE
ANDREWS
CULLOWHEE
FRANKLIN
ELLIJAY
LAKE TOXAWAY
HIGHLANDS
CLAYTON
MOUNTAIN REST
LIBERTY
CLEMSON COLLEGE
WESTMINSTER
CLEVELAND
TOCCOA
BELTON
GREENWOOD
CALHOUN FALLS
NEWBERRY
LITTLE MOUNTAIN
COLUMBIA
BATESBURG
CHAPPELLS
LOUDON
DECATUR
CHATTANOOGA
MCMINNVILLE
VALLEY HEAD
DALTON
GILLSVILLE
CANTON
DULUTH
ELBERTON
ATHENS
LEXINGTON
WASHINGTON
AUGUSTA
ATLANTA
ANNISTON
COLUMBUS
MACON
SAVANNAH

Figure 1.

SEISMOLOGICAL REPORTS FOR MARCH, 1916.

By W. J. HUMPHREYS, Professor in charge of Seismological Investigations.

[Dated: Weather Bureau, Washington, D. C., May 1, 1916.]

TABLE 1.—*Noninstrumental earthquake reports, March, 1916.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
1916. Mar.	*H. m.*	ARIZONA.	° ′	° ′			*Secs.*			
30	5 47	Nogales	31 20	110 52	3	1	5	Rumbling		S. F. Noon.
		CALIFORNIA.								
1	19 15	Los Alamos	34 45	120 15		1				J. W. Robbins.
12	3 15	Imperial	32 50	115 35	4	1	2			D. C. Gale.
22	4 06	Mount Wilson	34 13	118 16	1		10		2 feebler shocks later	W. P. Hoge.
		NEVADA.								
10	22 30	Reno	39 32	119 49	1	1	2		Doors swung slightly	J. C. Jones.
		WASHINGTON.								
2	23 15	Cedar Falls	47 24	120 49	2	1	2			D. A. Brown.

TABLE 2.—*Instrumental seismological reports, March, 1916.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols see this REVIEW, January, 1916, p. 39.]

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.
Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants:

	V	T_o
E	10	17.4
N	10	15.6

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 16	.....	eL_E	22 46 44	.....	.....	.....	.....	
		eL_N	22 47 00	.....	.....	.....	.....	
		M_E	22 47 16	8	70	.....	.....	
		M_N	22 48 00	8	.....	60	.....	
		F	23 06 00	.....	.....	.....	.....	
31	.....	e	11 13 44	18	.....	.....	.....	
		M_E	11 14 20	18	40	.....	.....	
		M_N	11 17 26	11	.....	20	.....	
		F	11 34 ..	.....	.....	.....	.....	

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.
Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants:

	V	T_o
E	10	15.2
N	10	19

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 12	.....	e_N	7 36 40	4	.....	.....	.....	
		L_E	7 41 38	.....	.....	.....	.....	
		L_N	7 40 44	.....	.....	.....	.....	
		M_E	7 46 38	7	10	.....	.....	
		M_N	7 45 22	4	.....	10	.....	
		F_N	7 52 –	.....	.....	.....	.....	
		F_E	7 55 –	.....	.....	.....	.....	
25	.....	eL_N	0 03 22	6	.....	.....	.....	
		eL_E	0 04 14	5	.....	.....	.....	
		M_E	0 04 40	9	10	.....	.....	
		M_N	0 04 49	10	.....	10	.....	
		F	0 07 –	.....	.....	.....	.....	
31	.....	P_E	11 20 26	4	.....	.....	.....	Clock out of adjustment on N-S.
		L_E	11 25 21	11	.....	.....	.....	
		M_E	11 25 46	10	60	.....	.....	
		C_E	11 25 58	10	.....	.....	.....	
		F_E	11 34 09	8	.....	.....	.....	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long. 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 12	I_2	.....	3 12 30	.....	* 200	* 200	.....	Intensity II Rossi-Forel.

*Amplitude on instrument.

(No shocks recorded during January and February, 1916.)

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 63″ W. Elevation, 27.43 meters.

(*See* record of the Seismographic Station, University of Santa Clara.)

TABLE 2.—*Instrumental seismological reports, March, 1916*—Continued.

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Instrumental constants.....

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1915.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 9	.....	e.....	16 00 00	.....	.....	.....	.....	Distinct activity. Thickening of pen marks on both components.
		F.....	19 15 00	.....	.....	.....	.....	
15	.....	e.....	16 40 00	.....	.....	.....	.....	Very small but distinct wavelets on both components.
		F.....	16 47 00	.....	.....	.....	.....	
15	.....	e.....	17 03 00	.....	.....	.....	.....	Small waves, somewhat larger than preceding.
		F.....	17 05 00	.....	.....	.....	.....	
19	.....			.....	.....	.....	.....	Activity. Thickening of pen marks at intervals during day.
20	.....	e.....	18 00 00	.....	.....	.....	.....	Activity. Thickening of pen marks on E–W.
		F.....	18 42 00	.....	.....	.....	.....	
26	.....	e.....	16 00 00	.....	.....	.....	.....	Activity. Distinct, but very irregular waves.
		F.....	18 15 00	.....	.....	.....	.....	
30	.....	e.....	9 00 00	.....	.....	.....	.....	Quake reported from Fort de France, Martinique. Long irregular waves on E–W especially.
		F.....	11 15 00	.....	.....	.....	.....	

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

	V	T_0
Instrumental constants..	110	6.4

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 1	.....	L_E.....	19 54 50	.....	.....	.....	.....	Beginning and end lost in microseisms.
12	.....	P.....	7 37 25	.....	.....	.....	3,290	
		S.....	7 42 29	.....	.....	.....	.....	
		L?.....	7 45 25	.....	.....	.....	.....	
		L.....	7 47 30	.....	.....	.....	.....	
		F.....	8 15 00	.....	.....	.....	.....	
16	.....	L.....	23 02 55	.....	.....	.....	.....	P, S, and F lost in microseisms.
		F?.....	23 30 00	.....	.....	.....	.....	
28	.....	L.....	7 56 25	.....	.....	.....	.....	
		F.....	8 05 00	.....	.....	.....	.....	
29	.....	eP.....	19 00 38	.....	.....	.....	2,625	
		S.....	19 04 53	.....	.....	.....	.....	
		L.....	19 11 35	20	.....	.....	.....	
		F.....	19 25 00	.....	.....	.....	.....	
31	.....	P?.....	11 25 28	.....	.....	.....	3,360?	
		S?.....	11 30 36	.....	.....	.....	.....	
		M.....	11 34 30	.....	64	100	.....	
		F.....	12 15 00	.....	.....	.....	.....	
31	.....	e.....	16 56 30	.....	.....	.....	.....	All phases indeterminable.
		F.....	17 15 00	.....	.....	.....	.....	

District of Columbia. *Washington. Georgetown University.*

F. L. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: decayed diorite.

Instruments: Wiechert 200 kg., astatic, horizontal pendulums; 80 kg., vertical.

Astatic pendulums after Mainka, 130 kg.

		V	T_0	ϵ
Instrumental constants:	E	165	5.4	2.6
	N	143	5.2	3.4
	Z	*80*	*3.0*	*0*

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 12	.....	eP_E...	7 37 01	.....	.....	.....	.....	Wind markings. Measurements made from record of Mainka instrument. Wiechert does not show P.
		eP_N...	7 37 25	.....	.....	.....	.....	
		S_E.....	7 42 49	.....	.....	.....	.....	
		S_N.....	7 42 58	.....	.....	.....	.....	
		eL_N...	7 46 12	6	.....	.....	.....	No distinct M.
		eL_E...	7 46 18	6	.....	.....	.....	
		F_N.....	8 02 04	.....	.....	.....	.....	
		F_E.....	8 02 09	.....	.....	.....	.....	
16	.....	eP.....	22 54 13	.....	.....	.....	.....	Microseisms due to wind.
		S_E?...	22 58 26	.....	.....	.....	.....	
		S_N?...	22 58 32	.....	.....	.....	.....	
		eL_N...	23 02 05	.....	.....	.....	.....	
		eL_E...	23 02 10	.....	.....	.....	.....	
		L_E.....	23 04 08	10	.....	.....	.....	
		L_N.....	23 04 10	9	.....	.....	.....	
		F_E.....	23 17 00	.....	.....	.....	.....	
		F_N.....	23 20 00	.....	.....	.....	.....	
29	.....	eP_E?..	19 05 00	.....	.....	.....	.....	
		eP_N...	19 05 22	.....	.....	.....	.....	
		S_E.....	19 09 32	.....	.....	.....	.....	
		S_N.....	19 09 36	.....	.....	.....	.....	
		eL_N?..	19 13 54	.....	.....	.....	.....	eL_E not discernible.
		F.....	19 28 00	.....	.....	.....	.....	
29	.....	e.....	21 16 22	.....	.....	.....	.....	Microseisms present.
		i	21 17 11	.....	.....	.....	.....	
		F.....	21 18 00	.....	.....	.....	.....	
31	.....	eP_E...	11 23 03	.....	.....	.....	.....	Microseisms present.
		eP_N...	11 23 24	.....	.....	.....	.....	
		S_N?...	11 28 31	.....	.....	.....	.....	
		L.....	11 31 03	.....	.....	.....	.....	
		M_N....	11 34 09	12	.....	6	.....	
		M_E....	11 34 14	12	9	.....	.....	
		F.....	11 58 00	.....	.....	.....	.....	
31	.....	e.....	16 54 44	.....	.....	.....	.....	Microseisms present.
		eL_N?..	17 00 02	.....	.....	.....	.....	
		eL_E?..	17 00 11	.....	.....	.....	.....	
		L_N?...	17 01 07	.....	.....	.....	.....	
		L_E?...	17 01 16	.....	.....	.....	.....	
		F.....	17 38 00	.....	.....	.....	.....	
31	.....	e.....	18 19 18	.....	.....	.....	.....	Microseisms present.
		F.....	19 10 00	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, March, 1916*—Continued.

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. W. Merrymon.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant.. T_0 19.4.

1916.			H. m. s.	Sec.	μ	μ	Km.
Mar. 4	.....	P.....	7 20 00	.....	.....	.....	.....
		S.....	7 27 18	.....	.....	.....	.....
		L.....	7 35 36	22	.....	.....	.....
		M.....	7 44 06	.....	100	.....	.....
		C.....	7 55 42	.....	.....	.....	.....
		F.....	8 32 24	.....	.....	.....	.....
12	.....	P.....	7 50 48	.....	.....	.....	.....
		L.....	8 01 06	22	.....	.....	.....
		M.....	8 05 12	20	.....	.....	.....
		C.....	8 10 18	.....	.....	.....	.....
		F.....	8 24 54	.....	.....	.....	.....
16	.....	e.....	22 57 12	.....	.....	.....	.....
		M.....	22 59 12	.....	20	.....	.....
		F.....	23 05 12	.....	.....	.....	.....
18	.....	P.....	1 15 12	.....	.....	.....	.....
		L.....	1 20 00	24	.....	.....	.....
		M.....	1 25 12	.....	20	.....	.....
		C.....	1 29 06	.....	.....	.....	.....
		F.....	1 39 12	.....	.....	.....	.....
19	.....	P.....	12 10 06	.....	.....	.....	.....
		S.....	12 17 42	.....	.....	.....	.....
		L.....	12 23 42	23	.....	.....	.....
		M.....	12 30 54	.....	70	.....	.....
		C.....	12 36 48	.....	.....	.....	.....
		F.....	13 06 24	.....	.....	.....	.....
19	.....	eP.....	23 37 06	.....	.....	.....	.....
		S.....	23 43 42	.....	.....	.....	.....
		L.....	23 51 06	22	.....	.....	.....
		M.....	23 54 48	.....	20	.....	.....
		C.....	23 59 24	.....	.....	.....	.....
		F.....	24 02 06	.....	.....	.....	.....
23	.....	P.....	9 00 48	.....	.....	.....	.....
		S.....	9 03 54	.....	.....	.....	.....
		L.....	9 06 36	24	.....	.....	.....
		M.....	9 10 12	.....	40	.....	.....
		C.....	9 14 24	.....	.....	.....	.....
		F.....	9 33 12	.....	.....	.....	.....
26	.....	P.....	0 13 12	.....	.....	.....	.....
		S.....	0 19 30	.....	.....	.....	.....
		L.....	0 25 24	24	.....	.....	.....
		M.....	0 33 36	.....	110	.....	.....
		C.....	0 41 00	.....	.....	.....	.....
		F.....	3 20 30	.....	.....	.....	.....
27	.....	eL.....	23 08 54	.....	.....	.....	.....
		M.....	23 14 24	.....	10	.....	.....
		C.....	23 17 36	.....	.....	.....	.....
		F.....	23 27 36	.....	.....	.....	.....
31	.....	P.....	11 24 12	.....	.....	.....	.....
		L.....	11 26 00	.....	.....	.....	.....
		M.....	11 27 12	.....	30	.....	.....
		C.....	11 32 00	.....	.....	.....	.....
		F.....	11 56 00	.....	.....	.....	.....

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants.. V T_0 ε
E 177 3.4 4
N 205 3.4 4

1916.			H. m. s.	Sec.	μ	μ	Km.
Mar. 31	.....	P_N?...	11 16 12	.....	.....	.....	.....
		P_E....	11 16 13	.....	.....	.....	.....
		L.....	11 27 01	.....	.....	.....	.....
		M_E....	11 27 19	12	4	.....	.....
		M_N....	11 27 48	.....	.....	4	.....
		F.....	11 55 00	.....	.....	.....	.....

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. V T_0
E 10 32
N 10 27

1916.			H. m. s.	Sec.	μ	μ	Km.
Mar. 12	.....	P_E....	7 33 20	.....	.....	.....	.....
		L_E....	7 40 16	5	.....	.....	.....
		L_N....	7 41 40	6	.....	.....	.....
		M_E....	7 48 08	5	10	.....	.....
		M_N....	7 49 10	6	.....	20	.....
		F.....	7 57 00	.....	.....	.....	.....
31	.....	eL.....	11 30 10	.....	.....	.....	.....
		M_E....	11 34 20	10	50	.....	.....
		M_N....	11 35 28	9	.....	50	.....
		F.....	11 39 00	.....	.....	.....	.....

Massachusetts. *Cambridge. Harvard University Seismographic Station,* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants.. V T_0 ε:1
E 80 23 0
N 50 25 4:1

1916.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 4	.....	*O*?....	*7 39 14*	.....	.....	.....	8,130?	P and S heavily masked by microseisms, of 5s to 6s period.
		eP_E?..	7 50 48	.....	.....	.....	.....	
		S?.....	8 00 08	77	.....	.....	.....	
		?.....	8 08 12	.....	.....	.....	.....	
		eL?....	8 15 10	.....	.....	.....	.....	
		L.....	8 17 40	20	.....	.....	.....	
		C.....	8 22 00	.....	.....	.....	.....	
		F?.....	8 45 30	.....	.....	.....	.....	F in microseisms.
7	.....	L_E....	19 38 06	17	.....	.....	.....	e to F in microseisms.
		L_E....	19 38 59	20	.....	.....	.....	3 waves in first L_E and 1 in second.
8	.....	*O*.....	*3 46 23*	.....	.....	.....	0	Minute local shock.
		iE.....	3 46 26	10	.....	.....	.....	
		F.....	3 46 36	.....	.....	.....	.....	
12	.....	*O*?....	*7 31 15*	.....	.....	.....	3,490?	P & S in microseisms.
		eP.....	7 37 55	.....	.....	.....	.....	Record of dubious interpretation; may be much more distant.
		S.....	7 43 11	9	.....	.....	.....	
		eL_E...	7 46 31	8	.....	.....	.....	
		L.....	7 49 35	20	.....	.....	.....	
		L.....	7 49 68	.....	.....	.....	.....	
		F.....	8 25 00	.....	.....	.....	.....	
16	.....	*O*.....	*22 50 00*	.....	.....	.....	.....	P and S masked by microseisms. N–S out of commission.
		eL_E?..	23 02 50	16	.....	.....	.....	
		L.....	23 04 06	12	.....	.....	.....	
		F?.....	23 28 30	.....	.....	.....	.....	
20	.....	*O*.....	*21 04 33*	.....	.....	.....	290	Local shock; not reported as felt.
		P.....	21 05 15	.....	.....	.....	.....	
		L.....	21 05 47	.....	.....	.....	.....	
		M.....	21 05 51	.....	62	.....	.....	
		F.....	21 06 17	.....	.....	.....	.....	
25?	.....	*O*?....	*25 00 00*	.....	.....	.....	.....	Day of *O* undetermined.
26	.....	eL_E?..	0 50 02	.....	.....	.....	.....	
		L.....	0 50 49	27	.....	.....	.....	
		L.....	0 55 43	20	.....	.....	.....	
		F.....	1 06 00	.....	.....	.....	.....	
31	.....	*O*?....	*11 10 50*	.....	.....	.....	4,220?	
		eP?....	11 18 24	.....	.....	.....	.....	
		S?.....	11 24 24	.....	.....	.....	.....	
		eL_E?..	11 27 27	11	.....	.....	.....	
		L.....	11 30 38	8	.....	.....	.....	
		e_N....	11 31 07	6	.....	.....	.....	
		eL_E?..	11 31 36	.....	.....	.....	.....	Amplitudes, except for M_E, diminish.
		eL_N...	11 31 42	8	.....	.....	.....	
		M_E....	11 32 38	15	.....	.....	.....	
		M_E....	11 35 00	13	.....	.....	.....	
		F.....	12 15 00	.....	.....	.....	.....	

O—time at origin.

TABLE 2.—*Instrumental seismological reports, March, 1916*—Continued.

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instruments: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants.. V 80, T_0 7, ε 5:1

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1916. Mar. 12	I_r	ePg_N	7 35 00				670	
		Sg_N	7 36 26					
		Mg_N	7 37 57					
		F	7 40 00					F in microseisms.
12	I	eg_N	7 42 00					
		Lg_N	7 43 20					
		F	7 44 00					F in microseisms.
31	II_r	eP	11 24 00					
		S?	11 26 30					
		L?	11 27 15					
		M	11 29 11					
		F	11 38 00					

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants.. V 80, T_0 7, ε 5:1

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1916. Mar. 12	III_r	ePg_N	7 35 30					P_g?
		Sg_E	7 38 15					
		Sg_N	7 38 20					
		Lg_E	7 41 40					
		Lg_N	7 42 00					
		Mg_E	7 44 15	6	7			
		Mg_N	7 44 20	8		6		
		Fg_N	7 59 30					
		Fg_E	7 59 50					
29		Mg_E?	19 02 00					No record on N–S, pens not working properly on either component on Mar. 29.
		Fg_E?	19 06 00					
31	III_r	iPg_E	11 17 45					
		iPg_N	11 18 00					
		Sg_E	11 22 40					
		Sg_N	11 23 20					
		Lg_E	11 28 40					
		Lg_N	11 28 45					
		Mg_E	11 31 00	10	24			
		Mg_N	11 31 10	10		12		
		Fg_E	11 49 00					
		Fg_N	11 50 00					Microseisms on 3d. 4th, 5th, 8th, 9th, Severe microseisms on 15th, 16th, and 17th, consisting of groups of damped sine waves, period of 6s. About 40 groups per hour. Mild microseisms on 19th, 20th, and 21st.

New York. *Fordham. Fordham University.* W. C. Repetti, S. J.

Lat., 40° 57′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert 80 kg.

Instrumental constants.. E: V 72, T_0 7.2, ε 1.5; N: V 73, T_0 7.2, ε 3.75

(Report for March, 1916, not received.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kgm., horizontal pendulums (mechanical registration.)

Instrumental constants.. E: V 13, T_0 22, ε 4:1; N: V 14, T_0 25, ε 4:1

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1916. Mar. 16	.....	eLg_E	23 00 55	10				Microseisms.
		eLg_N	23 02 01	14–6				
		Fg_E	23 09 00					
		Fg_N	23 12 30					
31	.....	eg_N	11 28 31	7				
		Lg_E	11 29 59	6–10				
		Lg_N	11 30 02	8–18		36		
		Fg_E	11 42 00					
		Fg_N	11 50 00					

Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori 100 kg.

Instrumental constants.. V 10, T_0 20

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1916. Mar. 1	.....	P_N	19 50 16					Distance and direction unknown.
		P_E	19 50 22					
		Fg_E	19 56 00					
		Fg_N	19 57 00					
21	.....	P_N	19 56 56				398	Direction unknown.
		P_E	19 56 58					
		L	19 57 44					
		M_N	19 57 50			30		
		Mg_E	19 57 56		40			
		Fg_E	19 59 46					
		Fg_N	19 59 58					
27	.....	P_N	13 43 38				51	Wave moved NE–SW.
		L	13 43 40					No record on E–W, clock stopped.
		M	13 43 46			180		
		F	13 44 14					
29	.....	P_N	10 08 56				103	Direction SW.
		P_E	10 09 00					
		L_N	10 09 05					
		M_N	10 09 06			2180		
		L_E	10 09 09					
		Mg_E	10 09 10		1600			
		F_E	10 10 50					
		F_N	10 11 28					

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. H. M. Pease.

Lat., 18° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.. E: V 10, T_0 21.4; N: V 10, T_0 21.1

(No earthquakes recorded in March, 1916.)

TABLE 2.—*Instrumental seismological reports, March, 1916*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants: V T_0; E 10 15; N 10 16

1916.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 12	.....	e.....	7 38 08	.....	.....	.....	.....	All phases indeterminable.
		F.....	8 00 00	.....	.....	.....	.....	
16	.....	L.....	23 02 48	.....	.....	.....	.....	Microseisms present.
		F.....	23 15 00	.....	.....	.....	.....	
28	.....	L.....	7 55 50	.....	.....	.....	.....	
		F.....	8 05 00	.....	.....	.....	.....	
31	.....	e.....	11 21 14	.....	.....	.....	.....	Very faint record, most pronounced on N–S.
		M.....	11 31 15	.....	.....	100	.....	
		F.....	12 00 00	.....	.....	.....	.....	
31	.....	e.....	16 56 33	.....	.....	.....	.....	Phases indeterminable.
		M.....	16 57 15	.....	.....	17	.....	
		F.....	17 15 00	.....	.....	.....	.....	

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants: V 120 T_0 26

1916.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 1	.....	eL_E...	19 53 12	24	.....	.....	.....	
		L_E....	19 57 00	14	.....	.....	.....	
		F.....	20 13 00	.....	.....	.....	.....	
12	.....	*O*.....	*7 51 10*	.....	.....	.....	3,900	
		P_N....	7 38 21	.....	.....	.....	.....	
		S.....	7 44 02	.....	.....	.....	.....	
		eL_E...	7 47 24	20	.....	.....	.....	
		eL_N...	7 48 36	9	.....	.....	.....	
		L_E....	7 49 00	.....	.....	.....	.....	
		F.....	8 15 00	.....	.....	.....	.....	
16	.....	*O*?....	*22 50 49*	.....	.....	.....	1,900?	
		eP?....	22 54 50	.....	.....	.....	.....	
		S_E?...	22 58 03	.....	.....	.....	.....	
		eL.....	23 00 42	20	.....	.....	.....	
		M.....	23 02 00	10	.....	.....	.....	
		F.....	23 25 00	.....	.....	.....	.....	
26	.....	L_E....	0 46 42	60	.....	.....	.....	
		L_N....	0 53 36	60	.....	.....	.....	
		F.....	1 12 00	.....	.....	.....	.....	
28	.....	eL_E...	7 56 00	15	.....	.....	.....	Some record precedes but failed to interpret it.
		eL_N...	7 56 30	15	.....	.....	.....	
		F.....	8 10 00	.....	.....	.....	.....	
29	.....	*O*.....	*18 59 58*	.....	.....	.....	3,300	
		P.....	19 06 22	2	.....	.....	.....	
		PR1....	19 07 22	.....	.....	.....	.....	
		L_N....	19 14 18	20	.....	.....	.....	
		L_E....	19 14 24	20	.....	.....	.....	
		L.....	19 15 00	18	.....	.....	.....	
		F.....	19 30 00	.....	.....	.....	.....	
31	.....	i_E....	11 19 32	.....	.....	.....	.....	
		e_E....	11 23 06	12	.....	.....	.....	
		e_N....	11 23 24	.....	.....	.....	.....	
		eL.....	11 29 18	20	.....	.....	.....	
		M.....	11 29 48	.....	60	30	.....	
		F.....	12 20 00	.....	.....	.....	.....	
31	.....	e.....	16 55 00	.....	.....	.....	.....	
		F.....	17 15 00	.....	.....	.....	.....	

TABLE 3.—*Late seismological reports.* (*Instrumental.*)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants: V T_0 ϵ; E 13 22 4:1; N 14 25 4:1

1916.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 1	.....	e_E.....	13 53 21	48	.....	.....	.....	
		e_N.....	13 53 36	36	.....	.....	.....	
		?$_N$.....	14 07 16	48	.....	.....	.....	
		?$_E$.....	14 07 32	59	.....	.....	.....	
		M_E.....	14 19 48	26	231	.....	.....	
		M_N.....	14 21 47	23	.....	286	.....	
		F_N.....	15 44 00	.....	.....	.....	.....	
		F_E.....	15 59 00	.....	.....	.....	.....	
13	.....	eP_E...	6 40 01	5	.....	.....	.....	
		eP_N...	6 41 09	4–7	.....	.....	.....	
		?$_E$.....	6 41 10	5–7	.....	.....	.....	
		?$_E$.....	6 57 31	13	.....	.....	.....	
		?$_N$.....	6 57 40	12	.....	.....	.....	
		eL_N...	7 27 17	21	.....	.....	.....	
		eL_E...	7 27 25	28	.....	.....	.....	
		F_N.....	8 02 00	.....	.....	.....	.....	
		F_E.....	8 09 00	.....	.....	.....	.....	
13	.....	eP_E...	8 42 29	4	.....	.....	.....	
		eP_N...	8 42 40	4	.....	.....	.....	
		?$_N$.....	8 43 32	4	.....	.....	.....	
		?$_E$.....	8 43 32	4	.....	.....	.....	
		?$_N$.....	8 47 12	12	.....	.....	.....	
		?$_E$.....	8 47 37	8	.....	.....	.....	
		?$_N$.....	8 52 45	7	.....	.....	.....	
		L_N.....	9 00 07	46	.....	.....	.....	
		L_E.....	9 00 23	52	.....	.....	.....	
		F_N.....	10 54 00	.....	.....	.....	.....	
		F_E.....	11 00 00	.....	.....	.....	.....	
24	.....	e_N.....	7 22 22	6	.....	.....	.....	Microseisms.
		L_N.....	7 31 10	40	.....	.....	.....	
		L_E.....	7 31 22	41	.....	.....	.....	
		F_E.....	7 59 00	.....	.....	.....	.....	
		F_N.....	8 06 30	.....	.....	.....	.....	
26	.....	eL_N...	13 20 56	20	.....	.....	.....	
		eL_E...	13 26 44	20	.....	.....	.....	
		F_N.....	13 32 00	.....	.....	.....	.....	
		F_E.....	13 48 00	.....	.....	.....	.....	
31	.....	e_E.....	18 19 20	4	.....	.....	.....	
		e_N.....	18 19 22	4	.....	.....	.....	
		L_E.....	18 33 43	39	.....	.....	.....	
		L_N.....	18 37 04	31	.....	.....	.....	
		F_E.....	18 56 30	.....	.....	.....	.....	
		F_N.....	18 59 00	.....	.....	.....	.....	
1916.								
Feb. 1	.....	L_N.....	8 34 51	15	.....	.....	.....	
		L_E.....	8 36 44	23	.....	.....	.....	
		F_E.....	8 58 00	.....	.....	.....	.....	
		F_N.....	9 04 00	.....	.....	.....	.....	
3	.....	e_N.....	5 16 40	4–9	.....	.....	.....	
		e_E.....	5 20 24	.....	.....	.....	.....	
		F_E.....	5 28 00	.....	.....	.....	.....	
		F_N.....	5 30 00	.....	.....	.....	.....	
6	.....	e_E.....	22 11 12	5	.....	.....	.....	
		e_N.....	22 11 33	7	.....	.....	.....	
		eL_N...	22 18 50	20	.....	.....	.....	
		eL_E...	22 23 22	18	.....	.....	.....	
		M_N.....	22 31 25	20	.....	79	.....	
		F_E.....	23 52 00	.....	.....	.....	.....	
7	.....	F_N.....	0 05 00	.....	.....	.....	.....	
8	.....	e_N.....	15 49 12	7	.....	.....	.....	
		F_N.....	15 57 00	.....	.....	.....	.....	
		L_E.....	16 16 52	16	.....	.....	.....	
		F_E.....	16 19 00	.....	.....	.....	.....	
15	.....	e_N.....	11 50 52	5	.....	.....	.....	
		e_E.....	11 50 54	4	.....	.....	.....	
		eL_E...	11 58 54	4–11	.....	.....	.....	
		L_N.....	11 59 12	10	.....	.....	.....	
		M_N.....	11 59 48	9	.....	50	.....	
		F_E.....	12 22 00	.....	.....	.....	.....	
		F_N.....	12 29 00	.....	.....	.....	.....	

TABLE 3.—*Late seismological reports*—Continued.

New York. *Ithaca. Cornell University*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.								
Feb. 20	.....	S_E	18 05 38	13	.....	.....	.....	
		S_N	18 07 40	9	.....	.....	.....	
		eL_E	18 17 06	18	.....	.....	.....	
		eL_N	18 17 12	13	.....	.....	.....	
		F_E	19 20 00	.....	.....	.....	.....	
		F_N	19 22 00	.....	.....	.....	.....	
21	.....	e_N	23 43 22	2	.....	.....	.....	
		e_E	23 43 23	2–4	.....	.....	.....	
		F_N	23 45 00	.....	.....	.....	.....	
		F_E	23 49 30	.....	.....	.....	.....	
27	.....	P_N	20 27 59	4	.....	.....	.....	
		P_E	20 28 18	3–4	.....	.....	.....	
		$?_E$	20 29 22	4–6	.....	.....	.....	
		$?_N$	20 29 23	7	.....	.....	.....	
		S_N	20 33 30	10	.....	.....	.....	S_E indistinct.
		L_E	20 35 49	.....	.....	.....	.....	
		L_N	20 38 09	29	.....	.....	.....	
		M_N	20 41 46	16	.....	757	.....	
		F_E	22 04 00	.....	.....	.....	.....	
		F_N	22 05 00	.....	.....	.....	.....	

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. H. M. Pease.

Lat. 18° 09′ N., long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.		V	T_0
	E	10	21.4
	N	10	21.1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 6	.....	eL_E	22 36 28	24	.....	.....	.....	
		eL_N	22 41 55	24	.....	.....	.....	
		M_N	22 44 20	24	.....	30	.....	
		M_E	22 45 00	24	10	.....	.....	
		F	23 08 00	.....	.....	.....	.....	
27	.....	P	20 26 11	2	.....	.....	.....	Apparently two shocks, a short time apart, the second being much heavier than the first.
		S_N	20 30 20	8	.....	.....	.....	
		S_E	20 30 35	10	.....	.....	.....	
		L	20 33 40	16	.....	.....	.....	
		M_E	20 36 10	16	900	.....	.....	
		M_N	20 38 30	16	.....	2,400	.....	
		C_N	20 45 00	.....	.....	.....	.....	
		C_E	20 46 00	.....	.....	.....	.....	
		F_N	21 07 00	.....	.....	.....	.....	
		F_E	21 23 00	.....	.....	.....	.....	

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants.		V	T_0	c:1
	E	80	23	0
	N	50	25	4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 6	.....	i	11 14 39	10	.....	.....	.....	e and F uncertain among waves of about 7ˢ period on E-W. Microseisms of 2.6ˢ period on N-S.
		L?	11 15 40	15	.....	.....	.....	
8	.....	e_E	15 39 14	13	.....	.....	.....	
		L	15 40 14	15	.....	.....	.....	
			15 40 47	.....	.....	.....	.....	
		i	15 52 17	.....	.....	.....	.....	
		L	16 14 46	20	.....	.....	.....	
		L	16 21 20	13	.....	.....	.....	
		F?	16 35 00	.....	.....	.....	.....	

SEISMOLOGICAL DISPATCHES.[1]

Rio de Janeiro, via Galveston, Tex., Mar. 1, 1916.

An earthquake of considerable intensity was registered by the seismograph instruments in the Government observatory here this morning. The disturbance was approximately 5,700 kilometers distant from Rio de Janeiro. (Mexican cable to N. Y. Herald.)

Ambato, Ecuador, Mar. 8, 1916.

Tunguragua volcano, in this Province, has been in eruption for several days. The city of Ambato and the surrounding region are almost in darkness on account of falling ashes. During the night the flames from the volcano are visible at a great distance. The people of Ambato are greatly alarmed, fearing a catastrophe. (Assoc. Press.)

Rome, Mar. 12, 1916, 10:15 p. m.—via Paris, Mar. 13, 1916, 1:40 a. m.

Earthquake shocks, lasting from 10 to 20 seconds, were felt in the region represented by a triangle with sides running between Venice, Ancona, and Florence. The observations made at Florence observatory indicated that the epicenter was about 300 miles distant, probably in the Adriatic Sea. No damage has been reported. (Assoc. Press.)

Calcutta, Mar. 25, 1916.

The first scientific survey of the effects of the destructive earthquake which had its center in Russian Turkestan in 1910, has just been completed by a party under the leadership of Dr. Aurel Stein. The quake produced some very extensive geographical changes, and is believed by many to have been the most violent seismic disturbance which has occurred in several centuries. At one point the fall of a whole mountain completely blocked the Bartang River, converting the Serezpamir gorge into an Alpine lake 15 miles long. (Assoc. Press.)

Panama, Mar. 29, 1916.

Two earthquake shocks occurred to-day, one at 5 o'clock this morning and the other this afternoon. No damage resulted. The earlier shock was the most severe. It lasted 1 minute and 20 seconds and reached the third category of intensity in the seismograph wave motions and showed a width of 22 millimeters. Most of the Isthmian population was awakened by the disturbance. This is the second severe shock in the last 24 months, the first taking place on May 18, 1914, and having an intensity of the sixth category. There were numerous tremors during the day, but, like an extremely slight shock last Monday, these were barely noticeable. (———)

CORRIGENDUM.

Instrumental report, Toronto, Canada, MONTHLY WEATHER REVIEW, February, 1916. Page 94, column 2, Feb. 27, P should be $20^h\ 29^m\ 12^s$.

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University.

SECTION VI.—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological and seismological work and studies:

Alexander, William H.
What the United States Weather Bureau is doing in California. (*In* Journal of the Cleveland engineering society. Cleveland. March, 1916. v. 8, p. 333–355.)

American climatological and clinical association.
Transactions, 1915, v. 31. Philadelphia. 1915. xxxi, 210 p. 24 cm.

Batavia. Royal magnetical and meteorological observatory.
Observations, v. 35, 1912. Batavia. 1915. xxvi, 96 p. 3 pl. 36½ cm.

Braak, C[ornelis].
Het klimaat van Nieuw-Guinea. Weltevreden. 1914. p. 179–225. 24½ cm. (Overgedrukt uit het Natuurkundig tijdschrift voor Ned.-Indië, deel 73, tweede aflevering.)

Earl, Geo. G.
The hurricane of Sept. 29th, 1915, and subsequent heavy rainfalls. Report . . . to Sewerage and water board of New Orleans. [New Orleans. 1915.] 18 p. 23 cm.

Eredia, Filippo.
Norme per l'impianto e per il funzionamento delle stazioni termo-udometriche. Roma. 1916. 41 p. 26 cm. (Estratto dalla Rivista meteorico-agraria, anno 37, n. 1.)
Sul temporale verificatosi a Tripoli nell' ottobre 1915, e sulla distribuzione dei temporali in Tripolitania. Roma. 1916. 17 p. (Estratto dal Bolletino informazioni delle colonie, n. 12, 1915.)
Le variazioni del clima in Italia. Roma. 1915. 23 p. 27 cm. (Estratto dagli Atti, X congresso internazionale di geografia, Roma, 27 marzo–3 aprile 1913.)

Fergusson, S. P.
The value of high-level meteorological data in forecasting changes of temperature—a contribution to the meteorology of Mount Rose, Nevada. Reno. [1915.] 30 p. 23 cm. (Nevada agric. exper. station. Bulletin no. 83, technical.)

Freybe, O[tto].
Die mittlere jährlichen Niederschlagsverhältnisse der Provinz Hessen-Nassau und Umgebung. Beilage zu der Niederschlagskarte der Provinz Hessen-Nassau und Umgebung. Berlin. 1913. 49 p. 22½ cm.
Niederschlagskarte der Provinz Hessen-Nassau und Nachbarschaft, auf Grund zwanzigjähriger Beobachtungen. Berlin. [1913.] wall map, 102 x 104½ cm.

Fogel, Edwin Miller.
Beliefs and superstitions of the Pennsylvania Germans. Philadelphia. 1915. iv, 387 p. 25 cm. ["Weather," p. 221–241.]

Galli, Ignazio.
Fulmini globulari nell' anno 1915. [Roma. 1916.] 14 p. 29 cm. (Estratto dagli Atti della Pont. accad. romana dei Nuovi Lincei, anno 69, sess. II[a] del 16 gennaio 1916.)

Gesemann, Gerhard.
Regenzauber in Deutschland. Braunschweig. 1913. 96 p. 23½ cm. (Inaug.-Diss.—Kiel.)

Hill, E. V.
Ventilation requirements and test methods. (*In* Journal of the Western society of engineers. Chicago. Feb., 1916. v. 21, no. 2.)

Hinselmann, Emil J. N. Brandt.
Mond und Wetter in Jahre 1916. Hannover. 1916. 5 p. tables. 20 cm.

Hunt, H[enry] A[mbrose].
The climate and meteorology of Australia. Melbourne. 1914. p. 121–162. 24½ cm. (Australia. Commonwealth bureau of meteorology. Bulletin no. 9. Reprinted from the Federal handbook on Australia, 1914.)

Johansson, Osc[ar] V[ilhelm].
Einige Studien über die monatlichen Temperaturextreme. Helsingfors. 1914. 114 p. map. 24 cm. (Ofversigt af Finska vetenskaps-societetens förhandlingar. bd. 55. 1912–1913. afd. A. no: 17.)

Levin, Emil.
Zur Klimatologie und Hydrologie des Peenegebietes. (Abflussvorgang der Peene.) Berlin. 1914. 51 p. plates. 33½ cm. (Inaug.-Diss.—Greifswald.)

Maryland. State weather service commission.
Report, 1914 and 1915. Baltimore. 1916. 7 p. 25½ cm.

Negro, Carlo.
Sul clima della Libia attraverso i tempi storici. Memoria II. Roma. 1915. 71 p. 29 cm. (Estratto dalle Memorie della Pont. accad. romana dei Nuovi Lincei, ser. II, v. 1.)

Ohly, Chr.
Die klimatischen Bodenzonen und ihre charakteristischen Bodenbildungen. Wien. *etc.* 1913. 45 p. 25½ cm. (*Sonderabdruck:* Internationale Mitteilungen für Bodenkunde.)

Oña (Spain). Colegio Máximo de la Cómpañía de Jesús.
Observaciones meteorológicas, [1915]. Oña. 1916. unp. 23½ cm.

Pettersson, O.
Klimatförändringar i historisk och förhistorisk tid. Uppsala & Stockholm. 1913. 81 p. plates. 31½ cm. (K. Svenska vetenskapsakademiens handlingar, bd. 51, n:o 2.)
Om solfläcksfenomenets periodicitet och dess samband med klimatets förändringar. Uppsala & Stockholm. 64 p. plate. 31½ cm. (K. Svenska vetenskapsakademiens handlingar, bd. 53, n:o 1.)

Pool, Venus W., & McKay, M. B.
Climatic conditions as related to carcospora beticola. Washington. 1916. p. 21–60. plate. 26 cm. (*Reprint from* Journal of agricultural research, v. 6, no. 1.)

Rainfall, American Samoa. [Samoan & English.] (*In* O le fa átonu o Amerika Samoa. Pago Pago. Ianuari, 1916. v. 14, num. 1.)

Rasmussen, Knud, & *others.*
The first Thule expedition, 1912. (*In* Meddelelser om Grønland, udgivne af Komm. f. ledelsen af de geolog. og geograf. undersøgelser i Grønland. København. 1915. bd. 51, 2. afd. p. 285–425. plates. 28 cm.) [Meteorological observations, by P. Freuchen, p. 415–425.]

Reed, William Gardner.
Report of the Meteorological station at Berkeley, California, for the year ending June 30, 1914. Berkeley. [1916.] p. 373–439. plates. 27 cm. (University of California publications in geography, v. 1, no. 9.)

Reed, William Gardner, & White, Marshall K.
Rainfall data of Berkeley, California, II. Berkeley. 1916. p. 83–116. 27 cm. (University of California publications in engineering, v. 1, no. 6.)
[See this issue of the REVIEW, p. 123.]

Sandström, J. W.
Meteorologische Studien im schwedischen Hochgebirge. Göteborg. 1916. 48 p. 24½ cm.

Spain. Observatorio central meteorológico.
Resumen de las observaciones, 1913. Madrid. 1915. lxxxvii, 584 p. 25 cm. (v. 7.)
Resumen de las observaciones, 1901–1903. Madrid. 1915. xiii, 396 p. 25 cm. (v. 8.)

Switzerland. Abteilung für Wasserwirtschaft.
Grafische Darstellung der Schweizerischen hydrometrischen Beobachtungen im Jahre 1913. [In German and French.] Bern. 1915. 14 p. 27 fold. pl. 38 cm.

Toronto observatory.
Results of meteorological, magnetical, and seismological observations, 1914. Toronto. 1915. 48 p. 19½ cm.

Tous y Biaggi, José.
Sobre un nuevo sistema de barómetro. Barcelona. 1914. 9 p. plate. 30½ cm. (Memorias de la Real academia de ciencias y artes de Barcelona, 3[a] época, v. 11, núm. 1.)

Uruguay. Instituto meteorológico nacional.
Datos del Observatorio central, Montevideo. Rio de la Plata—Puerto de Montevideo. Año 1915. [Montevideo. 1916.] 56 p. 31 cm.

Zi-ka-wei. Observatoire magnétique, météorologique et sismologique.
Bulletin des observations, tome 37, annee 1911. Météorologie. Chang-hai. 1915. xxxi, 153 p. plates. 31 cm.
Bulletin des observations, tome 37, année 1911. Sismologie. Chang-hai. 1915. C. 20 p. 31 cm.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The subjoined titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

American society of civil engineers. Proceedings. New York. v. 42. April, 1916.

Duryea, Edwin, Jr., & Haehl, H. L. A study of the depth of annual evaporation from Lake Conchos, Mexico. Discussion by C. E. Grunsky and H. A. Whitney. p. 559–582.

Leighton, M. O., Babb, Cyrus C. & others. Discussion on [the Progress report of the Special committee on] floods and flood prevention. p. 591–604.

London, Edinburgh, and Dublin philospophical magazine. London. v. 31. April, 1916.

Deeley, R. M. The theory of the winds. p. 399–400.

Physical review. Lancaster. ser. 2. v. 6. 1915.

Humphreys, W[illiam] J[ackson]. The thunderstorm. p. 516. [Abstract of a paper presented at the joint meeting of the Physical society and Section B of the A. A. A. S., in Berkeley, August 3, 1915.]

Royal meteorological society. Quarterly journal. London. v. 42. January, 1916.

Dines, J[ohn] S[omers]. The mounting and illumination of barometers and the accuracy obtainable in the readings. p. 1–11.

Rainfall of the British East Africa protectorate. p. 12.

Comissopulos, N. A. On the seasonal variability of rainfall over the British Isles. p. 13–21.

Brodie, Fred[eric]k J. The incidence of bright sunshine over the United Kingdom during the thirty years 1881–1910. p. 23–43.

Galloway, W[illiam]. Remarkable cloud phenomena. p. 45–48.

Brooks, C. E. Notes on an old MS. weather diary in the papers of the Perth literary and antiquarian society. p. 51–55.

Hurst, H. E. Note on high temperatures experienced in Egypt in June, 1915. p. 55–56.

Mr. F. Gaster. p. 57. [Obituary.]

Scottish geographical magazine. Edinburgh. v. 32. April, 1916.

The origin of ground ice. p. 200–201. [Refers to frazil, rather than true ground ice].

Symons's meteorological magazine. London. v. 51. March, 1916.

Exceptional rainstorm in Malta. p. 17.

Curtis, R. H. A practical application of anemometry. p. 18–19. [Derailments of trains by wind avoided by the use of anemometers with alarm bell.]

Bonacina, C. W. L. Relation of rainfall to cloud-level. p. 20–23.

Terrestrial magnetism and atmospheric electricity. Baltimore. v. 21. March, 1916.

Swann, W. F. G. On the ionization of the upper atmosphere. p. 1–8.

Störmer, Carl. Biographical sketch of Aksel Steen. p.19–20. [With portrait.]

U. S. Department of agriculture. Yearbook. Washington. 1915.

Nunn, Roscoe. Stories of the atmosphere. p. 317–327.

U. S. National advisory committee for aeronautics. First annual report. Washington. 1915.

Wilson, Edwin Bidwell. Theory of an aeroplane encountering gusts. p. 52–75.

Herschel, W. H. The Pitot tube and other anemometers for aeroplanes. p. 79–100.

Marvin, C[harles] F. Preliminary report on the problem of the atmosphere in relation to aeronautics. p. 129–130.

Académie des sciences. Comptes rendus. Paris. Tome 162. 13 mars 1916.

Störmer, Carl. L'altitude des aurores boréales observées de Bossekop pendant le printemps de l'année 1913. p. 390–392.

Aérophile. Paris. 24 année. Février 1916.

Antarès, Jean H. La navigation aérienne et la météorologie. p. 36–38.

Archives des sciences physiques et naturelles. Genève. 4 pér. Tome 41. 15 février 1916.

Birkeland, K. Les rayons corpusculaires du soleil qui pénètrent dans l'atmosphère terrestre sont-ils négatifs ou positifs? p. 109–124.

Physikalische Zeitschrift. Leipzig. 17. Jahrgang. 1. Februar 1916.

Nölke, Fr[iedrich]. Zur Erklärung der beim Geschützdonner, bei grossen Explosionen usw. beobachteten Fortpflanzungseigentümlichkeiten des Schalles. p. 31–35.

Hemel en dampkring. Den Haag. 13 jaarg. Februari 1916.

Stok, J. P. van der. Het klimaat van Nederlandsch-Indië. p. 152–156.

SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF THE MONTH, MARCH, 1916.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, D.C., May 2, 1916.]

PRESSURE.

The distribution of the mean atmospheric pressure over the United States and Canada and the prevailing direction of the winds are graphically shown on Chart VII, while the average values for the month at the several stations, with the departures from the normal, are shown in Tables I and III.

For the month as a whole, the mean barometric pressure was above the normal in all districts from the Rocky Mountains westward and also locally in the Upper Lake region and along the immediate Gulf Coast. The plus departures, however, were generally small, except that they were rather pronounced from the Central Plateau districts westward to the Pacific. To the eastward of the Rockies, the monthly averages were below the normal, except in the local areas previously mentioned, with rather pronounced negative departures, especially in the central and north Atlantic Coast districts.

At the beginning of the month, a low-pressure area moved rapidly eastward from the southern Plains region, and was followed by a high of considerable magnitude, but from the 5th to the 9th another marked low moved across the central portions of the country from the Pacific to the Atlantic. This depression reached the New England coast as a storm of great intensity, the barometer at Eastport, Me., reading 28.92 inches on the 9th at 8 a. m. During the following 4 or 5 days, pressure was relatively high quite generally throughout the country, but about the middle of the month considerably lower readings obtained in eastern districts, which, however, were soon displaced by a high area advancing from the west. During the first 2 or 3 days of the third decade, marked low pressure again obtained from the Rocky Mountains eastward, and unsettled barometric conditions, with a tendency to rather low readings in most districts, continued until the end of the month.

The distribution of the highs and lows was generally favorable for southerly winds in the South Atlantic and Gulf States and northerly over all other districts east of the Rockies, while variable winds obtained to the westward.

TEMPERATURE.

Freezing temperature was recorded at some time during the month in all sections, except in the extreme southern portions and along the Pacific Coast. Temperatures were below zero in the northern States from Montana eastward and as far south as central Kansas, while in portions of the northern Plains States they were more than 20° below zero. Readings of 90° occured in southeastern Kansas, over most of Texas and Oklahoma, and in the southern portions of Arizona and California, while they were 100° at Fort Worth, Tex., and Yuma, Ariz. The highest previous records for March were equaled or exceeded in western Louisiana, northern Texas, southwestern Arizona, the southern portion of California and Utah, and in Nevada, while the lowest were equaled or exceeded in the northeastern districts. At Wichita, Kans., there occurred a maximum as high as any previous record and also a minimum 1 degree lower than heretofore recorded in March for 28 years.

The monthly mean temperature was below the normal in most eastern and northeastern districts, while it was higher than the average in most central and western sections, the greatest plus departures occurring along the eastern Rocky Mountain slope.

Killing frosts occurred in northern Florida, and light frosts as far south as the central portion of that State on the 5th, 9th, and 16th, and frosts were general in the southeastern States on the 17th and 18th.

PRECIPITATION.

During the first 2 or 3 days of the month rain or snow fell in nearly all portions of the country, but the falls were generally light, and during the following day or two fair weather was the rule. About the middle of the first decade, unsettled, showery weather set in over the Pacific Coast States and by the end of the decade it had reached the Atlantic Coast, but again the falls were mostly only moderate to light. The second decade brought generally fair weather which continued throughout that period, except for some showers about the middle of the month in the eastern States. Unsettled, showery weather was the rule in most districts during the third decade, except that fair weather predominated near the close of the month.

For the month as a whole, the precipitation was very irregularly distributed, being much in excess of the normal along the north Pacific coast and slightly above to the eastward along the northern border to New York, and likewise at points in the upper Mississippi and lower Missouri valleys and the central Rocky Mountain region. It was below the normal in northern New York, southern New England, and on the California coast, and was markedly deficient in practically all the Gulf States, while almost no precipitation occurred in Texas until the last day of the month, when moderate to heavy rains fell in the northern and central portions. In extreme southwestern Texas and at points along the eastern Rocky Mountain slope, no rain, or only very slight amounts, occurred.

The deficiency of rainfall along the immediate central Gulf Coast was between 4 and 5 inches, and rain was much needed in the Florida Peninsula at the end of the month. Heavy rainfall and melting snow caused general floods during the latter part of the month in Ohio, northern Illinois, lower Michigan, Wisconsin, and North Dakota, while a destructive storm crossed Indiana on the night of the 21st, causing some loss of life and property damage amounting to over $1,000,000. This storm is again referred to at the end of the summary.

SNOWFALL.

The month opened with the ground generally covered with snow in the central and northern portions of the country, but it disappeared from the central districts during the first week. The snow line moved northward during the remainder of the month, so that at the close the only areas covered by snow were the extreme northeastern States and the upper and western Lake region.

The snowfall was much greater than usual from New Jersey and central Pennsylvania northward, and it also was above the normal in most districts north of the Ohio River, from 2 to 3 feet occurring in the central portions of New England and New York. In the far western mountains some additions were made to the snowfall already stored, so that at the close of the month the outlook for water for irrigation and other purposes in nearly all the western districts was the best for several years.

GENERAL SUMMARY.

The weather conditions were generally favorable for farm work in most southern sections, except that in Texas planting was delayed by dry weather. The development of vegetation was delayed by cold weather in the Middle Atlantic States, but in the central Rocky Mountain districts it was in advance of the season. The cold weather did considerable damage to truck in the southeastern States and much replanting was necessary, while some damage resulted to the peach and cherry blooms in that section as well as to early fruits in Arizona and southern New Mexico.

LOCAL STORMS IN MARCH.

The following is a brief summary of a report of a storm that passed over the north-central portion of Indiana on March 21, 1916, submitted by the official in charge of the local office of the Weather Bureau at Indianapolis, Ind.

One of the most destructive wind storms that has visited this section for a number of years swept across the north-central portion of Indiana between 9:30 and 11:30 p. m., March 21, 1916. The greatest destructive force of the storm was felt in a comparatively narrow belt, extending from the southern part of Newton County eastward to the northern portion of Jay County, on the opposite side of the State. Owing to its occurrence at night, times given for the passage of the disturbance vary somewhat; but a close comparison of the different reports secured indicates that the damaging wind was experienced in the western part of the path between 9:30 and 10 p. m., and that it crossed Cass and Miami Counties between 11 and 11:30 p. m. This would require an eastward progress of from 60 to 70 miles an hour for the translation of the disturbance, but that rate does not, of course, represent the velocity of the wind which swept the path.

No thunderstorms were reported during the day in any part of Indiana or the adjoining States, but numerous such storms occurred during the following night over the northern portions of Illinois and Ohio, accompanied by heavy rain and hail, or rain and sleet.

Practically all reports describe the destruction as due to a high wind which lasted about 5 minutes, and swept a path of from 2 to 10 miles wide. While two persons reported the observation of a funnel cloud of the tornado character, a number stated that no such cloud was observed; but it is probable that the darkness made the observation of clouds a matter of uncertainty. Practically all of the reports agree that the destructive wind blew from the northwest to southeast (in a few instances from west to east); and there is no mention made of any sudden shift in direction. In one or two places the débris appeared to be scattered in several directions, and one person reported observing broken timbers having a twisted appearance.

The greatest destruction appears to have been wrought in the counties of White, Cass, the northern parts of Grant and Blackford, and the southern part of Wells, but damage to a considerable extent occurred at practically all points in the path of the storm. Four persons were killed by the collapse of buildings, one was burned to death in the wreckage of his home, and many, probably a hundred, more or less severely injured. Numerous barns and buildings were demolished, several cars of a passenger train near Hanfield, Grant County, were blown from the track, and a great deal of live stock was killed. Telegraph, telephone, trolley, and electric-light wires in many parts of the region affected were blown down and the services seriously crippled. The property damage throughout the path of the storm, as conservatively estimated, will total between $1,000,000 and $1,500,000.

Average accumulated departures for March, 1916.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	Ins.	Ins.	Ins.	Perct.		Perct.	
New England	27.3	−5.6	− 3.9	2.76	−1.10	−2.40	5.2	−0.5	73	− 2
Middle Atlantic	35.6	−4.5	+ 0.2	3.35	−0.30	−1.60	5.6	−0.1	68	− 4
South Atlantic	52.6	−1.2	+ 6.8	1.86	−2.50	−5.70	3.9	−1.0	65	−10
Florida Peninsula	66.4	−3.9	+ 1.3	0.58	−1.70	−4.40	2.2	−1.6	71	− 6
East Gulf	56.6	−0.6	+ 5.8	1.89	−3.90	−7.20	4.1	−0.9	67	− 6
West Gulf	61.9	+4.0	+10.4	1.16	−2.00	−2.50	3.9	−1.2	61	−11
Ohio Valley and Tennessee	41.7	−2.4	+ 1.7	3.50	−0.90	+0.10	6.1	+0.1	70	− 1
Lower Lakes	27.3	−5.6	− 2.8	3.00	+0.40	+0.60	6.0	−0.6	78	+ 2
Upper Lakes	23.7	−3.9	− 3.6	2.68	+0.40	+0.60	6.2	+0.2	80	+ 1
North Dakota	21.2	+0.3	− 9.9	1.67	+0.70	+0.90	5.8	+0.2	84	+ 6
Upper Mississippi Valley	36.5	+0.5	+ 1.7	1.81	−0.60	+1.10	6.0	+0.3	75	+ 2
Missouri Valley	40.7	+4.6	+ 2.1	1.46	−0.50	−2.30	5.3	−0.4	71	− 1
Northern slope	37.3	+6.5	− 4.4	0.93	−0.20	+0.10	5.9	+0.5	62	− 5
Middle slope	48.3	+5.8	+ 5.0	0.90	−0.60	−0.40	4.5	−0.1	52	− 8
Southern slope	60.2	+7.1	+14.7	0.78	−0.10	−1.20	2.8	−1.6	37	−15
Southern Plateau	55.0	+4.0	+ 4.6	0.52	0.00	+1.80	2.9	−0.8	40	+ 4
Middle Plateau	45.2	+4.2	+ 3.5	1.13	−0.10	+1.40	3.8	−1.2	51	− 5
Northern Plateau	43.8	+3.6	− 3.5	1.97	+0.40	+1.50	7.3	+1.5	63	− 3
North Pacific	45.4	+0.6	− 4.4	9.45	+4.40	+5.60	7.8	+1.2	81	+ 6
Middle Pacific	53.6	+2.3	+ 2.1	1.82	−2.40	+2.70	4.2	−1.2	70	− 4
South Pacific	59.1	+4.0	+ 1.8	1.45	−1.20	+6.20	3.5	−2.3	72	+ 1

WEATHER CONDITIONS OVER THE NORTH ATLANTIC DURING MARCH, 1915.

The data presented are for March, 1915, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month. Chart IX (XLIV–33) shows for March 1915 the averages of pressure, temperature, and prevailing direction of the wind at 7 a. m., 75th Meridian time, together with the locations and courses of the more severe storms of the month.

PRESSURE.

The distribution of pressure for the month was abnormal in nearly all respects, and the average values were below the normal over the greater part of the ocean. The highest monthly average of the barometric readings

for any one 5-degree square was 30.05 inches, occurring in the vicinity of Ireland and there was no locality between the 20th and 77th meridians where the mean of the barometric readings for the month was as high as 30 inches. A limited area with a crest of 30 inches surrounded the Canary Islands, while there was another area of the same intensity and of somewhat greater extent, central near the south coast of Ireland. The most remarkable feature of the average pressure distribution was the low of 29.3 inches central near St. Johns, Newfoundland, where the normal pressure is about 29.8 inches. It can be seen that the two great centers of action, the Azores HIGH and the Icelandic LOW, were practically missing, and this fact, together with the development of the low mentioned above, was responsible for the unusual conditions of wind and weather over certain parts of the ocean referrred to later on.

STORMS.

The number of gales east of the 23rd meridian was somewhat below the normal, while in the central and western regions the opposite held true. The greatest number of gales in any one 5-degree square occurred between the 40th and 45th parallels and 40th and 45th meridians, where they were reported on 12 days, or a percentage of 39, the normal percentage for the square being 21. Three of these gales occurred in the first decade of the month, 2 in the second, and 7 in the last 11 days. The distribution of gales throughout the month varied considerably in different localities, as in the waters adjacent to the American coast, between the 35th and 40th parallels, 9 of the 10 gales reported occurred on the first 12 days of the month, while in some regions in mid-ocean they were more evenly divided and in others most of the heavy winds prevailed during the first and last decades of the month, leaving the middle period comparatively free.

Four storm tracks are shown on Chart IX, and there were other disturbances whose paths were either too uncertain to plot accurately or else their centers were indeterminate on account of lack of observations.

On March 1 a LOW (I on Chart IX) was central near St. Johns, Newfoundland, and light to moderate west and northwest winds prevailed over a large area south of the center. It moved about 7 degrees south within the next 24 hours, the wind increasing somewhat in force, and then recurved to the northeast. From the 2d to the 4th the rate and direction of movement were comparatively uniform, the wind continuing to increase in velocity. During the 4th, when the center was near latitude 47°, longitude 41°, several vessels in the area west of the 40th meridian and between the 30th and 40th parallels, reported heavy gales of over 60 miles an hour, with rain and hail. The storm then turned toward the southwest, moving rapidly, as on the 5th the center was near latitude 38°, longitude 47°, while the condition of the wind and weather was similar to that of the day before. The disturbance then turned toward the northeast, decreasing in its rate of movement, and on the 6th it was near latitude 40°, longitude 44°. In the regions north and west of the center winds of gale force were reported, while toward the east and south they were moderate. This LOW then began to fill in, and on the 7th it was not well enough defined to plot, and no trace of it could be seen on the 8th. This storm was remarkable for its irregularity in both rate of speed and direction of movement, although it was not accompanied by especially heavy gales.

On March 8 a LOW of 29.20 inches (II on Chart IX) was central about 10° east of Hatteras, causing north and northwest gales along the coast between Norfolk and central Florida. This moved in a northeasterly direction, increasing in intensity, and on the 9th was central near latitude 39°, longitude 58°. The barometer fell to 28.60 inches and the wind increased in force, the steamship *Sylvanian* (Br.), about 4° west of the center, reporting a northeasterly hurricane of 90 miles or over, and several other vessels in the same general locality encountered extremely heavy winds with rain and hail. Continuing in the same direction, it was central near latitude 43°, longitude 52°, on the 10th; the barometer remained practically stationary, and gales of from 40 to 60 miles an hour prevailed over a large area, with hail and rain. The path of the storm then turned at right angles to the northwest, and on the 11th the center was near St. Johns, Newfoundland, the barometer having risen to 28.90 inches and the wind moderated considerably, although three vessels east of Hatteras, between the 67th and 72d meridians, reported northwest gales of from 40 to 50 miles.

On Chart III (XLIII–34, March 1915) showing tracks of centers of LOWS for March, 1915, a LOW (III on Chart IX) is shown that first appeared in eastern California on the evening of March 12. This moved in a southeasterly direction, and did not appear within the limits of Chart IX until the morning of the 14th, when it was located near the southeast corner of the boundary between New Mexico and Texas. From this point the movement was nearly due east, until the evening of the 16th, when the LOW was central in the vicinity of Raleigh, N. C. From this point it turned slightly toward the north, and on the 17th was near latitude 39°, longitude 65°, winds of from 35 to 50 miles prevailing in the southwest quadrant. It then curved still more toward the north, and on the 18th was about 6 latitude degrees east of Halifax, the barometer falling to 29 inches and the wind increasing southward of the center with heavy gales, hail, and rain over a large area. The storm then curved toward the northwest, and decreasing in its rate of movement was central at Sydney, C. B. I., on the 19th. The barometer had risen slightly since the day before, and the storm area had decreased somewhat in extent, although westerly and northwesterly gales of from 40 to 50 miles, with hail and rain, were encountered south of the center. The LOW continued its movement toward the northwest, and on the 20th was over the Gulf of St. Lawrence, the barometer having risen and the wind decreased in force since the 19th.

On March 21 a LOW of 29.35 inches (IV on Chart IX) is shown near latitude 42°, longitude 64°. The wind ranged from light to moderate, while rain, hail, and snow were all reported by a number of vessels. From this point it rapidly moved eastward, and on the 22d was near latitude 44°, longitude 48°, the barometer having fallen to 28.68 inches, and the winds increased in force; gales of over 50 miles an hour were encountered in its southern quadrant. It continued in its easterly direction, and on the 23d was near latitude 44°, longitude 40°, the barometer falling to 28.49 inches, although the velocity of the wind had not changed materially since the day before. LOW IV then curved sharply toward the north, the rate of translation having decreased, and on the 24th it was near latitude 46°, longitude 38°, the pressure and wind force having changed but little. From this point it changed its course toward the east, and on the 25th recurved again toward the north, so that on the 26th it was near latitude 48°, longitude 38°, where a number

of vessels south of the center reported gales of from 40 to 50 miles.

From March 27 to 31, inclusive, a practically stationary LOW was central near St. Johns, Newfoundland. The barometer readings ranged from 29.28 inches on the 29th to 28.60 inches on the 31st, and heavy gales with rain and hail prevailed on every day during the period with the exception of the 30th, when only moderate winds were reported.

TEMPERATURE.

In mid-ocean and in the waters adjacent to the European coast the temperatures were as a rule somewhat above the normal, the departures ranging from 0 degrees near the coast of France to +4 in a number of 5-degree squares between the 45th and 55th parallels and the 20th and 40th meridians. The abnormal distribution of the mean pressure for the month was responsible for the unusual condition of the wind and temperature that were influenced by the low, central near St. Johns. The cyclonic character of the circulation around the center was very marked, and the easterly winds that prevailed in the northern part of the area caused positive temperature departures of from 2 to 5 degrees, while south of Portland, in the waters adjacent to the American coast, where the winds were from the north and the northwest, they ranged from 0 near the 43d parallel to −7 degrees off the coast of Florida, and were about the same in the northern portion of the Gulf of Mexico. The departures at a number of Canadian and United States Weather Bureau stations on the Atlantic and Gulf coasts were as follows: St. Johns, N. F., +5.1°; Sydney, C. B. I., +3.4°; Eastport, +1.0°; Portland, +0.2°; Nantucket, −1.8°; New York, −1.1°; Baltimore, −2.5°; Norfolk, −5.3°; Hatteras, −6.2°; Charleston, −7.6; Jacksonville, −6.1°; Key West, −7.2°; Pensacola, −8.0°; New Orleans, −7.0°; and Galveston, −8.5°.

The lowest temperature recorded during the month was 18° F. on the 5th, 8th, 9th, and 13th, and occurred in the 5-degree square between the 50th and 55th parallels and the 55th and 60th meridians. The highest temperature was 82°F. and occurred on a number of days in the waters adjacent to the Isthmus of Panama.

FOG.

The percentage of days with fog off the Banks of Newfoundland, as given on the normal Meteorological Chart for March ranges from 40 to 45, while in March, 1915, fog was only observed on one day in that locality. This was probably due to the almost continuous presence of the low area central near St. Johns and the consequent heavy westerly and northwesterly winds that prevailed during the greater part of the month. The greatest number of days on which fog was observed occurred in the two 5-degree squares between the 45th and 50th parallels and the 15th and 25th meridians, where it was reported on three days, or a percentage of 10; the normal percentage for that locality being 5. The steamer tracks were remarkably free from fog, and over a large portion of the routes none was observed.

PRECIPITATION.

Snow was reported on 6 days off the New England coast, where the maximum amount fell. No snow was reported from east of the 50th meridian. Hail occurred on 5 days in the same region where the number of days with snow was the highest and was rarely seen on the steamer routes.

Maximum wind velocities.

Stations.	Date.	Velocity.	Directions.	Stations.	Date.	Velocity.	Directions.
		Mls./hr.				*Mls./hr.*	
Atlanta, Ga.	3	50	nw.	Mt. Tamalpais, Cal.	23	63	nw.
Do.	15	50	nw.	Do.	24	62	nw.
Block Island, R. I.	4	54	n.	Do.	27	54	nw.
Do.	5	52	nw.	Do.	30	57	n.
Do.	8	56	nw.	Nantucket, Mass.	3	63	ne.
Do.	9	52	w.	Do.	4	67	ne.
Do.	17	54	nw.	Nashville, Tenn.	7	52	w.
Buffalo, N. Y.	7	80	w.	Do.	22	51	sw.
Do.	8	56	sw.	New York, N. Y.	4	50	nw.
Do.	9	52	w.	Do.	5	64	nw.
Do.	10	66	w.	Do.	16	58	w.
Charlotte, N. C.	3	54	nw.	Do.	17	57	nw.
Do.	22	54	sw.	Do.	20	50	nw.
Chattanooga, Tenn	22	50	nw.	Norfolk, Va.	4	51	nw.
Cheyenne, Wyo.	2	50	nw.	North Head, Wash	2	66	s.
Do.	3	64	w.	Do.	5	64	s.
Do.	4	54	w.	Do.	7	70	s.
Do.	5	56	w.	Do.	8	59	s.
Do.	6	70	w.	Do.	19	56	s.
Do.	8	74	nw.	Do.	21	82	s.
Do.	9	50	nw.	Do.	24	60	se.
Do.	20	78	nw.	Do.	26	50	s.
Cincinnati, Ohio	7	52	w.	Oklahoma, Okla.	14	50	n.
Cleveland, Ohio	9	56	sw.	Pensacola, Fla.	25	51	s.
Columbus, Ohio	7	70	w.	Point Reyes Light, Cal.	1	64	nw.
Concordia, Kans.	21	52	nw.	Do.	4	56	s.
Dayton, Ohio	7	55	sw.	Do.	5	56	nw.
Del Rio, Tex.	24	50	nw.	Do.	22	70	nw.
Duluth, Minn.	9	57	w.	Do.	23	81	nw.
Eastport, Me.	8	56	ne.	Do.	24	50	nw.
Do.	9	56	ne.	Do.	28	58	nw.
El Paso, Tex.	21	50	w.	Pueblo, Colo.	21	50	w.
Do.	22	57	sw.	St. Louis, Mo.	22	54	w.
Erie, Pa.	6	53	se.	St. Joseph, Mo.	21	56	nw.
Do.	10	52	s.	Do.	22	56	nw.
Do.	27	52	e.	Salt Lake City, Utah	5	53	nw.
Evansville, Ind.	7	62	sw.	Sand Key, Fla.	8	52	nw.
Fort Smith, Ark.	25	52	sw.	Do.	16	50	n.
Green Bay, Wis.	22	50	n.	Sandy Hook, N. J.	4	52	nw.
Hatteras, N. C.	3	57	nw.	Do.	5	50	nw.
Do.	4	51	nw.	Savannah, Ga.	3	52	nw.
Indianapolis, Ind.	7	56	w.	Do.	15	50	nw.
Jacksonville, Fla.	22	52	sw.	Sheridan, Wyo.	21	50	nw.
Kansas City, Mo.	7	50	nw.	Sioux City, Iowa	6	58	nw.
Do.	21	60	w.	Do.	7	50	nw.
Do.	22	56	nw.	Toledo, Ohio	7	51	sw.
Lander, Wyo.	5	58	w.	Do.	9	57	sw.
Lexington, Ky.	7	62	nw.	Tatoosh Island, Wash.	2	61	sw.
Do.	22	56	w.	Do.	3	53	sw.
Lincoln, Nebr.	7	50	nw.	Do.	5	62	s.
Do.	21	50	nw.	Do.	7	58	s.
Do.	22	54	nw.	Do.	12	50	sw.
Louisville, Ky.	6	52	w.	Do.	14	56	ne.
Do.	7	72	w.	Do.	21	56	s.
Do.	22	70	w.	Do.	26	51	s.
Lynchburg, Va.	22	54	w.	Wichita, Kans.	21	50	w.
Memphis, Tenn.	7	50	w.				
Mt. Tamalpais, Cal.	1	60	sw.				
Do.	20	50	nw.				
Do.	21	58	nw.				

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data, as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, March, 1916.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	54.8	−2.3	Evergreen	94	22	Florence	18	16	2.99	−2.78	Bermuda	8.00	Camp Hill	0.88
Arizona	56.3	+3.7	2 stations	100	10†	Lakeside	4	25	1.35	+0.16	Carr's ranch	6.96	Mohawk	0.21
Arkansas	54.5	+1.7	do	91	21	Pond	11	3	1.93	−2.76	Brinkley	4.24	Fort Smith	0.68
California	53.0	+1.2	Indio	104	10	Tamarack	−14	22	3.38	−1.36	Crescent City	15.53	Bagdad	0.00
Colorado	39.5	+4.9	Two Buttes	88	19	Gunnison	−26	3	1.28	−0.19	Silverton	4.92	6 stations	T.
Florida	62.2	−3.2	Malabar	92	2	Orange City	24	17	0.88	−2.27	De Funiak Springs	3.76	2 stations	0.00
Georgia	54.2	−2.0	2 stations	89	25	2 stations	15	9†	1.95	−2.87	Clayton	3.68	St. George	0.25
Hawaii (February)	70.0	.....	Haiku Expt. Sta., Maui.	91	14	do	45	17†	3.01	.....	Kapahi Kauai	7.72	Waiopai Ranch, Maui.	0.00
Idaho	39.2	+2.3	2 stations	80	16†	Kilgore	−20	2	2.58	+0.86	Burke	8.94	Challis	0.15
Illinois	38.6	−0.7	3 stations	81	13†	Montrose	− 2	4	1.96	−1.03	Paw Paw	4.39	Edwardsville	0.95
Indiana	37.3	−3.9	Vincennes	79	24	Howe	− 3	3	2.63	−1.16	Bluffton	4.33	Monticello	0.75
Iowa	35.2	+1.9	Clarinda	80	12	Algona	−18	2	1.57	−0.20	Washington	5.80	Northboro	0.23
Kansas	47.8	+4.8	Toronto	96	21	Rainville	−11	3	1.22	−0.24	Pleasanton	4.43	5 stations	T.
Kentucky	43.5	−2.8	Beattyville	84	25	2 stations	4	4	3.39	−1.50	Maysville	5.50	Irvington	1.80
Louisiana	61.3	−0.2	Liberty Hill	93	21	Kelly	23	4	1.36	−3.20	Franklinton	3.55	Lakeside	0.00
Maryland and Delaware	35.9	−6.7	3 stations (Md.)	78	25†	Oakland, Md	− 3	11	3.83	+0.28	Frostburg, Md	6.84	Leonardtown, Md	1.87
Michigan	23.4	−5.7	Cassopolis	74	25	Humboldt	−38	17	2.90	+0.83	Eagle Harbor	6.10	Allegan	1.35
Minnesota	22.5	−2.5	Winnebago	65	24	Roseau	−44	1	1.56	+0.29	Winton	3.33	Waseca	0.46
Mississippi	56.6	−1.2	Anguilla	88	22	Booneville	20	16	3.51	−2.18	Clarksdale	6.53	Pearlington	0.97
Missouri	47.0	+1.3	Amoret	95	21	Maryville	− 2	3†	2.53	−0.65	Avalon	5.45	Tarkio	0.17
Montana	35.2	+5.6	Wilder	83	22	Whitewater	−34	2†	1.04	+0.02	Heron	7.42	Mildred Round-up	T.
Nebraska	41.4	+6.2	Geneva	88	12†	Callaway	−14	3	0.45	−0.68	Beatrice	1.60	Stratton	0.00
Nevada	45.2	+5.3	Logan	92	9	Gold Creek	− 2	6	0.74	−0.31	Jack Creek	2.70	Logan	0.00
New England	25.1	−5.7	Houlton, Me	74	27	Van Buren, Me	−23	22	2.83	−0.98	Portland, Me	5.22	Bloomfield, Vt	0.80
New Jersey	31.7	−6.3	Flemington	71	31	Culvers Lake	− 9	18	3.48	−0.57	Woodbine	4.96	Newark	2.38
New Mexico	48.3	+3.7	Artesia	95	13	Dulce	−17	3	0.95	+0.22	Tagique (near)	5.19	2 stations	T.
New York	24.0	−7.9	Indian Lake	70	26	North Lake	−31	18	3.30	+0.06	Liberty	6.24	Harkness	0.79
North Carolina	48.3	−2.2	2 stations	85	22†	Banners Elk	5	6	2.25	−2.28	Banners Elk	4.91	Mount Airy	0.97
North Dakota	20.3	−2.0	Orange	69	27	Cando	−45	1	1.48	+0.61	Steele	4.12	Lisbon	0.10
Ohio	34.7	−4.8	Portsmouth	87	25	3 stations	−10	18	4.15	+0.56	Bellpoint	6.32	Danbury	1.70
Oklahoma	55.3	+2.8	Weatherford	103	21	Hooker	2	3	1.63	−0.25	North Muskogee	4.96	2 stations	T.
Oregon	44.4	+0.8	Bend	83	12	Yonna	− 1	2	5.69	+4.04	Glenora	29.29	Merrill	0.17
Pennsylvania	30.7	−7.1	Uniontown	84	26	West Bingham	−31	18	4.12	+0.58	Somerset	8.84	Milford	2.20
Porto Rico	73.9	+0.1	Corozal	95	10	Aibonito	45	23	1.74	−1.92	Inabon Falls	7.00	Hacienda Destino	0.10
South Carolina	53.7	−0.9	Aiken	87	22	Mountain Rest	15	9	2.14	−1.72	Georgetown	5.57	Meriwether	0.82
South Dakota	33.7	+2.7	2 stations	79	19†	Pollock	−26	2	1.20	−0.09	Lead	4.79	Murdo	0.05
Tennessee	47.8	−1.6	Johnson City	87	26	Mountain City	7	1	3.24	−1.98	New River	5.02	Greeneville (near)	1.59
Texas	63.7	+4.6	2 stations	103	5	Stratford	1	3	0.64	−1.46	Hico	4.04	28 stations	0.00
Utah	41.0	+2.4	Kanab	85	14	Lone Tree	−15	3	1.93	+0.35	Silver Lake	6.73	Winder	0.13
Virginia	41.6	−3.5	Williamsburg	84	25	2 stations	− 1	1†	2.30	−1.58	Winchester	4.75	Hot Springs	0.72
Washington	41.6	+0.2	2 stations	78	10	Snyder's ranch	− 2	4	6.47	+3.57	Cedar Lake	24.60	Harrington	0.20
West Virginia	38.5	−4.2	Glenville	88	25	New Cumberland	− 4	18	4.88	+1.01	Pickens	9.88	Moundsville	2.49
Wisconsin	24.9	−3.6	Beloit	67	25	Deerskin Dam	−35	15	2.09	+0.31	Beloit	5.79	Mauston	0.72
Wyoming	34.9	+5.2	Moorcroft (near)	80	17	Eden	−25	1	1.15	−0.18	Moran	3.55	Deaver	0.01

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations, making simultaneous observations at 8 a. m. and 8 p. m., daily, 75th meridian time, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.80

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the successive rate ends.

In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred the greatest precipitation of any single storm has been given, also the greatest hourly fall during that storm.

The tipping-bucket mechanism is *dismounted* and removed when there is danger of snow or water freezing in the same. Table II records this condition by entering an asterisk (*).

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall.

Chart I.—Hydrographs for several of the principal rivers of the United States.

Chart II.—Tracks of centers of high areas; and

Chart III.—Tracks of centers of low areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading or (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea level and standard gravity.

Chart IV.—Temperature departures. This chart presents the departures of the monthly mean temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin "R," Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908 have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—Total precipitation. The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—Percentage of clear sky between sunrise and sunset. The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—Isobars and isotherms at sea level and prevailing wind directions. The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sea-level plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction, t_0–t, or temperature on the sea-level plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sea-level temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations; a few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—Total snowfall. This is based on the reports from regular and cooperative observers and shows the depth in inches and tenths of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

Chart IX.— Average values of pressure, temperature, and prevailing wind directions, and storm tracks over the North Atlantic Ocean, *for the corresponding month of last year.*

TABLE I.—*Climatological data for Weather Bureau stations, March, 1916.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01" or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
New England.							**27.3**	**– 5.6**										**73**	**2.76**	**– 1.1**										**5.2**		
Eastport	76	67	85	29.71	29.80	– .13	24.6	– 4.3	50	30	31	4	18	18	27	21	16	73	1.64	– 2.6	11	11,159	w.	56	ne.	9	10	8	13	5.7	15.7	T.
Greenville	1,070	6	....	28.65	29.86	.....	18.8	.....	63	28	30	–11	22	8	39	.....	.....	.....	2.35	.....	9	.....	ne.	.....	.....	.....	.....	.....	.....	.....	.....	23.5	....
Portland, Me	103	82	117	29.76	29.89	– .07	26.8	– 5.2	57	27	34	1	18	19	26	23	15	64	5.22	+ 1.5	12	7,922	n.	33	nw.	20	13	7	11	5.2	36.3	....
Concord	288	70	79	29.56	29.89	– .11	26.1	– 5.4	65	31	36	– 2	12	16	38	.....	.....	.....	3.01	– 0.4	10	4,800	nw.	26	nw.	24	17	6	8	4.1	38.2	T.
Burlington	404	11	48	29.47	29.94	– .06	20.7	– 6.6	57	31	30	– 5	18	12	32	.....	.....	.....	1.31	– 0.5	11	7,348	n.	39	s.	10	12	9	10	5.2	24.1	....
Northfield	876	12	60	28.95	29.94	– .06	19.0	– 7.2	60	28	31	–13	12	7	50	16	12	78	1.31	– 1.5	9	5,072	n.	31	nw.	17	13	7	11	5.0	22.0	T.
Boston	125	115	188	29.74	29.88	– .09	30.6	– 4.4	55	26	38	7	18	24	25	27	20	69	3.20	– 0.9	15	8,870	w.	36	ne.	8	16	4	11	4.6	33.0	....
Nantucket	12	14	90	29.83	29.84	– .14	30.4	– 6.4	46	31	36	9	18	25	16	28	25	79	3.60	– 0.4	16	13,967	nw.	67	ne.	4	12	7	12	5.8	22.9	T.
Block Island	26	11	46	29.85	29.88	– .10	30.4	– 5.5	52	31	35	10	18	26	17	29	26	83	1.73	– 2.6	12	16,776	nw.	56	nw.	8	14	5	12	5.5	11.6	....
Narragansett Pier	....	9	....	.....	.....	.....	29.3	– 5.7	55	31	37	2	18	22	24	.....	.....	.....	2.71	.....	14	.....	ne.	.....	.....	.....	19	2	10	.....	19.5	T.
Providence	160	215	251	29.70	29.88	– .10	29.4	– 6.3	60	31	37	5	18	22	26	26	21	73	2.46	– 2.2	14	11,759	nw.	49	nw.	13	11	11	9	5.2	19.1	....
Hartford	159	122	140	29.73	29.92	– .07	29.4	– 5.6	64	31	37	4	18	22	33	25	19	68	2.77	– 1.6	13	6,267	nw.	29	nw.	17	11	7	13	5.5	27.4	....
New Haven	106	117	155	29.79	29.91	– .08	31.0	– 4.4	66	31	38	3	18	24	28	26	20	67	4.08	– 0.4	17	8,403	nw.	34	nw.	4	11	10	10	5.4	29.0	....
Middle Atlantic States.							**35.6**	**– 4.5**										**68**	**3.35**	**– 0.3**										**5.6**		
Albany	97	102	115	29.83	29.95	– .06	26.0	– 6.1	59	31	34	– 1	17	18	28	23	17	72	3.99	+ 1.2	12	6,403	nw.	29	nw.	17	15	8	8	4.5	37.9	T.
Binghamton	871	10	69	28.97	29.93	– .09	25.0	– 7.0	58	30	34	– 6	18	16	34	.....	.....	.....	3.07	+ 0.4	15	3,243	nw.	22	w.	10	6	12	13	6.4	29.6	T.
New York	314	414	454	29.57	29.93	– .07	32.2	– 5.3	63	31	39	7	18	25	23	27	19	61	3.71	– 0.4	15	14,674	nw.	64	nw.	5	8	13	10	6.1	23.8	....
Harrisburg	374	94	104	29.55	29.97	– .06	33.3	– 4.5	68	31	40	6	18	26	32	30	23	68	4.14	+ 1.0	13	6,704	nw.	27	e.	28	9	9	13	5.8	10.5	....
Philadelphia	117	123	190	29.82	29.95	– .07	35.4	– 4.6	66	31	42	10	18	28	24	31	24	65	3.75	+ 0.3	12	9,260	nw.	37	nw.	5	10	8	13	5.8	9.3	....
Reading	325	81	98	29.60	29.96	.....	33.2	.....	69	31	41	5	18	26	31	29	22	65	3.93	+ 0.4	11	6,565	nw.	31	nw.	5	7	9	15	6.5	8.9	....
Scranton	805	111	119	29.06	29.96	– .06	28.9	– 6.0	66	26	37	– 1	18	21	32	26	22	75	5.74	+ 2.6	13	5,644	ne.	33	w.	5	8	13	10	5.8	38.0	....
Atlantic City	52	37	48	29.88	29.94	– .08	34.0	– 4.8	59	13	40	9	18	28	22	30	25	74	4.41	+ 0.7	13	7,285	nw.	38	ne.	28	10	7	14	6.0	7.1	....
Cape May	18	13	49	29.94	29.96	– .05	35.3	– 5.5	55	31	41	13	18	29	25	.....	.....	.....	4.79	+ 1.1	13	8,706	nw.	38	nw.	4	9	12	10	5.8	10.3	....
Sandy Hook	22	10	57	29.91	29.93	.....	31.4	.....	58	31	37	9	18	26	21	28	25	79	3.66	.....	14	14,317	nw.	52	nw.	4	12	8	11	5.4	17.5	....
Trenton	190	159	183	29.72	29.93	.....	32.2	.....	66	31	39	6	18	25	28	28	23	71	2.61	– 1.4	13	10,263	nw.	46	nw.	5	10	7	14	5.9	9.0	....
Baltimore	123	100	113	29.83	29.96	– .07	37.0	– 4.9	64	31	44	13	18	30	26	32	24	62	3.61	– 0.3	10	6,496	nw.	26	ne.	28	10	8	13	5.8	2.5	....
Washington	112	62	85	29.83	29.95	– .09	37.9	– 4.3	71	25	47	14	18	29	37	32	25	62	2.80	– 1.0	10	6,212	nw.	38	nw.	5	10	9	12	5.7	1.8	....
Lynchburg	681	153	188	29.18	29.94	– .11	44.6	– 0.8	82	25	56	18	16	33	37	37	29	59	1.32	– 2.5	8	7,075	nw.	54	w.	22	11	13	7	5.5	1.1	....
Norfolk	91	170	205	29.84	29.94	– .09	44.1	– 3.6	77	25	54	20	16	35	37	38	31	65	1.68	– 2.6	9	11,896	n.	51	nw.	4	15	8	8	4.2	2.5	....
Richmond	144	11	52	29.79	29.94	– .10	43.4	– 3.5	79	25	54	14	4	32	36	36	29	64	1.57	– 2.2	13	7,302	ne.	39	nw.	22	10	13	8	5.2	4.4	....
Wytheville	2,293	49	55	27.53	29.96	– .09	40.6	– 1.7	76	25	52	11	16	29	42	35	32	76	2.47	– 2.0	14	7,173	w.	42	w.	22	11	13	7	4.9	0.4	....
South Atlantic States.							**52.6**	**1.2**										**65**	**1.86**	**– 2.5**										**3.9**		
Asheville	2,255	70	84	27.59	29.98	– .08	44.5	– 0.4	76	14	56	13	16	32	43	37	31	67	1.74	– 3.3	10	8,601	nw.	37	nw.	15	14	9	8	4.1	1.8	....
Charlotte	773	153	161	29.11	29.96	– .09	49.8	– 1.0	77	25	61	21	16	39	33	42	34	59	1.38	– 3.2	9	10,465	sw	54	sw.	22	13	15	3	3.9	.....	....
Hatteras	11	12	50	29.94	29.94	– .10	48.4	– 3.0	68	25	55	29	4	42	29	44	39	74	2.30	– 3.2	10	14,513	sw.	57	nw.	3	7	16	8	5.7	T.	....
Manteo	12	4	46	.....	.....	.....	47.3	.....	75	25	38	25	4	36	.....	.....	.....	.....	2.80	– 2.2	7	.....	sw.	.....	.....	.....	9	10	12	.....	1.0	....
Raleigh	376	103	110	29.54	29.95	– .10	49.3	– 1.1	79	14	61	23	16	38	36	41	32	56	2.17	– 2.1	9	7,852	sw.	42	w.	22	8	13	10	5.5	T.	....
Wilmington	78	81	91	29.90	29.98	– .07	52.0	– 1.7	80	26	62	25	12	42	30	45	40	71	2.83	– 0.8	8	6,971	sw.	30	w.	8	17	7	7	3.7	.....	....
Charleston	48	11	92	29.96	30.01	– .05	55.2	– 2.0	78	14	65	29	9	45	29	48	42	68	1.96	– 1.8	6	9,510	sw.	36	w.	3	22	7	2	2.7	.....	....
Columbia, S. C	351	41	57	29.61	29.99	– .07	54.6	+ 0.6	81	22	66	26	9	43	37	45	36	57	1.98	– 1.7	6	7,954	sw.	46	sw.	22	18	7	6	3.5	.....	....
Augusta	180	89	57	29.80	30.00	– .06	55.7	– 0.2	84	25	68	27	9	43	38	48	42	67	1.39	– 3.5	5	6,712	nw.	39	w.	3	16	12	3	3.4	T.	....
Savannah	15	150	194	29.95	30.02	– .04	57.2	– 1.1	83	22	68	30	9	46	32	49	42	65	1.37	– 2.3	5	11,143	sw.	52	nw.	3	18	8	5	3.5	.....	....
Jacksonville	43	209	265	30.00	30.05	– .01	59.5	– 2.4	82	25	70	33	16	49	37	51	45	65	0.59	– 2.9	4	11,208	sw.	52	sw.	22	19	10	2	2.6	.....	....
Florida Peninsula.							**66.4**	**– 3.9**										**71**	**0.58**	**– 1.7**										**2.2**		
Key West	22	10	64	30.04	30.06	– .09	70.2	– 2.6	82	7	76	54	17	64	17	63	59	71	0.63	– 0.8	3	8,047	se.	30	n.	8	26	4	1	1.6	.....	....
Miami	25	71	79	30.05	30.08	.....	65.8	– 6.2	84	3	75	44	10	57	27	59	54	69	0.28	– 2.4	2	6,562	nw.	31	sw.	3	21	8	2	2.8	.....	....
Sand Key	23	39	72	30.02	30.05	– .00	69.4	.....	79	22	72	57	16	66	16	65	62	78	0.58	.....	3	11,189	ne.	52	nw.	8	25	5	1	1.7	.....	....
Tampa	35	79	96	30.04	30.08	+ .01	63.1	– 2.8	83	25	73	37	16	53	30	55	49	67	0.83	– 2.0	4	5,928	sw.	36	nw.	8	21	9	1	2.5	.....	....
East Gulf States.							**56.6**	**– 0.6**										**67**	**1.89**	**– 3.9**										**4.1**		
Atlanta	1,174	190	216	28.76	30.02	– .04	50.7	– 1.7	77	25	62	22	16	40	35	43	36	63	1.84	– 3.9	6	11,169	nw.	50	nw.	15	13	8	10	4.8	T.	....
Macon	370	78	87	29.62	30.02	– .04	54.7	– 0.1	82	25	67	26	16	42	38	48	43	70	1.38	– 4.1	7	6,500	nw.	32	nw.	3	16	11	4	3.6	.....	....
Thomasville	273	49	58	29.75	30.05	– .01	58.2	– 2.0	82	25	70	31	16	46	33	50	44	67	1.62	– 3.5	3	5,095	sw.	27	sw.	22	18	8	5	3.2	.....	....
Pensacola	56	140	182	30.01	30.07	+ .01	59.6	– 1.5	75	26	67	32	16	52	28	53	49	74	0.53	– 4.8	6	11,632	sw.	51	s.	25	16	11	4	4.0	T.	....
Anniston	741	9	57	29.24	30.04	– .02	52.2	– 0.3	81	25	64	23	16	40	39	.....	.....	.....	2.22	– 3.6	9	6,165	nw.	28	sw.	22	12	13	6	4.5	T.	....
Birmingham	700	11	48	29.27	30.05	– .01	52.8	– 2.4	82	25	64	23	16	41	35	45	37	61	3.01	– 2.8	7	6,745	s.	29	se.	25	12	11	8	4.8	T.	....
Mobile	57	125	161	30.00	30.06	.00	59.9	+ 0.8	83	22	69	33	16	50	28	53	48	72	2.69	– 4.5	8	8,962	sw.	46	se.	25	15	11	5	3.9	.....	....
Montgomery	223	100	112	29.80	30.05	– .01	56.6	– 1.3	84	25	68	28	16	45	32	48	41	61	2.54	– 3.8	8	6,463	nw.	31	nw.	3	14	9	8	4.3	.....	....
Meridian	375	85	93	29.63	30.04	– .01	56.2	– 0.1	84	22	68	28	16	44	38	48	42	64	2.34	– 3.3	3	6,023	sw.	30	nw.	25	15	9	7	4.6	.....	....
Vicksburg	247	65	74	29.76	30.05	+ .01	58.0	– 0.2	85	22	68	32	16	48	29	50	44	65	1.98	– 4.3	2	6,914	sw.	35	nw.	7	15	10	6	4.3	.....	....
New Orleans	51	76	84	30.00	30.06	+ .02	63.8	+ 1.8	82	22	74	39	16	54	31	56	52	75	0.64	– 4.7	3	6,319	sw.	32	nw.	8	16	11	4	3.6	.....	....
West Gulf States.							**61.9**	**+ 4.0**										**61**	**1.16**	**– 2.0**										**3.9**		
Shreveport	249	77	93	29.74	30.01	– .01	60.6	+ 2.4	89	21	73	33	4	49	35	51	43	61	1.88	– 2.6	3	7,392	s.	42	w.	6	14	13	4	3.9	.....	....
Bentonville	1,303	11	44	28.56	29.94	– .07	50.3	+ 3.0	89	21	62	17	3	38	37	.....	.....	.....	2.16	– 1.7	8	6,349	s.	30	nw.	22	15	7	9	4.5	T.	....
Fort Smith	457	79	94	29.48	29.96	– .05	54.8	+ 3.5	90	21	66	25	3	43	39	45	37	58	0.68	– 2.9	6	8,809	e.	52	sw.	25	16	6	9	4.3	T.	....
Little Rock	357	139	147	29.61	29.99	– .04	54.8	+ 2.1	86	21	66	30	4	44	35	47	39	62	1.59	– 3.4	5	9,562	sw.	42	nw.	7	15	7	9	4.7	T.	....
Brownsville	57	3	40	.....	.....	.....	71.4	.....	96	2	82	42	16	61	41	.....	.....	.....	0.07	.....	1	.....	s.	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Corpus Christi	20	69	77	29.99	30.01	+ .03	68.8	+ 4.4	90	7	76	50	3	62	29	61	57	75	0.00	– 1.8	0	12,080	se.	42	se.	24	9	17	5	4.8	.....	....
Dallas	512	109	117	29.44	29.98	.....	62.0	.....	96	21	75	24	3	49	38	.....	.....	.....	2.33	.....	4	9,674	se.	48	w.	31	12	11	8	4.4	.....	....
Fort Worth	670	106	114	29.24	29.95	– .03	62.4	+ 5.8	100	21	76	25	3	49	39	49	36	46	3.68	+ 1.9	4	10,217	s.	48	se.	24	14	8	9	4.5	.....	....
Galveston	54	106	114	29.98	30.04	+ .03	65.8	+ 3.5	78	7	71	48	3	61	20	60	56	77	0.25	– 2.6	2	9,802	s.	39	nw.	14	17	11	3	3.4	.....	....
Houston	138	111	121	29.89	30.04	.....	66.6	+ 3.1	89	22	77	42	3	56	31	.....	.....	.....	T.	.....	0	7,633	s.	31	se.	31	15	10	6	4.1	.....	....
Palestine	510	64	72	29.46	29.99	– .01	63.2	+ 4.7	90	21	75	31	3	51	36	52	45	59	0.47	– 3.0	1	8,287	s.	31	se.	24	21	7	3	3.0	.....	....
San Antonio	701	109	132	29.25	29.98	.00	68.6	+ 6.5	94	24	82	40	3	55	36	55	43	52	0.79	– 0.9	2	7,302	s.	42	n.	14	23	6	2	2.2	.....	....
Taylor	582	55	63	29.41	30.02	+ .03	64.8	+ 5.1	92	21	78	32	3	52	41	.....	.....	.....	0.12	– 2.5	2	9,803	s.	35	nw.	14	20	7	4	3.4	.....	....

TABLE I.—*Climatological data for Weather Bureau stations, March, 1916*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.											Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01" or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.											
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°	°F.	°F.	°f.	%	*In.*	*In.*		*Miles.*											0–10	*In.*	*In.*
							41.7	— 2.4										70	3.30	— 0.9													6.1		
Chattanooga	762	189	213	29.21	30.03	— .03	49.8	— 1.5	79	21	61	22	9	39	36	43	36	65	2.47	— 3.7	13	8,349	sw.	50	nw.	22	11	8	12	5.3	0.5	....
Knoxville	996	93	100	28.92	29.99	— .07	47.7	— 0.5	80	25	59	19	4	36	44	40	32	60	2.25	— 3.3	9	5,468	sw.	37	w.	22	11	8	12	5.4	1.0	....
Memphis	399	76	97	29.61	30.04	.00	52.0	— 0.1	80	21	61	29	16	43	36	45	39	64	2.22	— 3.6	8	8,557	sw.	50	w.	7	13	11	7	4.7	.....	....
Nashville	546	168	191	29.42	30.02	— .03	47.2	— 2.0	82	21	58	20	4	37	42	41	34	64	3.60	— 1.8	11	8,818	nw.	52	w.	7	12	6	13	5.5	0.8	....
Lexington	989	193	230	28.89	29.98	— .07	41.2	— 2.2	76	25	51	9	4	31	39	.....	.....	.....	3.30	— 1.4	14	11,331	sw.	62	nw.	7	10	5	16	6.0	3.9	....
Louisville	525	219	255	29.41	30.00	— .05	43.2	— 2.1	76	24	53	13	4	33	38	37	31	67	3.85	— 0.5	13	11,119	n.	72	w.	7	8	9	14	6.7	5.0	....
Evansville	431	130	175	29.51	29.99	— .05	43.6	— 1.0	75	24	53	14	4	34	41	38	33	70	2.56	— 2.0	11	10,029	nw.	62	sw.	7	5	17	9	6.2	6.1	....
Indianapolis	822	194	230	29.07	29.98	— .06	37.9	— 1.7	74	24	48	6	4	28	34	33	28	72	2.44	— 1.6	11	10,290	sw.	56	w.	7	6	7	18	6.8	6.5	....
Terre Haute	575	96	129	29.34	29.97	.....	39.6	.....	77	24	50	7	4	30	44	35	31	76	1.50	.....	10	8,949	n.	48	nw.	7	2	16	13	7.0	5.5	....
Cincinnati	628	11	51	29.28	29.98	— .07	38.9	— 3.9	76	25	49	8	4	29	41	34	30	75	3.34	— 0.3	15	7,253	n.	52	w.	7	6	12	13	6.3	6.0	....
Columbus	824	173	222	29.07	29.97	— .07	35.5	— 3.7	80	25	45	6	16	26	33	32	28	76	4.88	+ 1.7	14	9,789	nw.	70	w.	7	10	11	10	5.2	10.8	....
Dayton	899	181	216	28.97	29.95	.....	36.7	— 3.6	77	25	46	7	4	27	33	33	29	79	3.51	+ 0.1	14	9,130	n.	55	sw.	7	5	12	14	6.6	6.1	....
Pittsburgh	842	353	410	29.03	29.96	— .08	34.1	— 5.4	77	25	43	6	18	25	34	29	24	70	3.63	+ 0.6	17	9,718	nw.	46	sw.	10	7	5	19	7.1	11.0	....
Elkins	1,940	41	50	27.85	29.97	— .08	36.8	— 2.3	82	25	48	6	16	26	45	32	28	76	5.53	+ 1.5	20	4,113	w.	30	nw.	22	3	9	19	7.6	13.4	....
Parkersburg	638	77	84	29.31	29.98	— .07	39.4	— 2.9	82	25	49	13	16	30	39	34	29	72	4.48	+ 0.7	17	5,162	nw.	45	nw.	7	12	5	14	5.8	5.7	....
Lower Lake Region.							27.3	— 5.6										78	3.00	+ 0.4													6.0		
Buffalo	767	247	280	29.09	29.95	— .07	27.1	— 4.1	67	26	35	— 1	18	19	28	24	20	78	3.52	+ 0.9	17	12,813	w.	80	w.	7	4	11	16	6.7	24.5	T.
Canton	448	10	61	29.45	29.95	.....	19.0	— 8.7	53	31	28	—11	18	10	29	.....	.....	.....	1.60	— 1.2	12	7,458	w.	42	sw.	10	17	7	7	3.9	19.8	1.0
Oswego	335	76	91	29.57	29.95	— .06	24.4	— 7.4	59	26	31	— 1	18	18	25	23	18	75	1.16	— 1.7	17	8,813	nw.	39	w.	10	5	10	16	6.8	19.5	....
Rochester	523	97	113	29.38	29.97	— .05	26.0	— 5.3	62	31	34	— 3	18	19	28	23	18	74	4.29	+ 1.4	22	7,470	w.	38	w.	10	9	6	16	6.4	43.8	T.
Syracuse	597	97	113	29.29	29.96	— .06	24.6	— 6.8	57	26	32	— 4	18	18	29	22	17	77	3.36	+ 1.0	20	8,191	nw.	44	sw.	10	7	11	13	6.3	27.8	1.0
Erie	714	130	166	29.16	29.95	— .07	27.4	— 5.7	63	26	36	— 5	18	19	31	24	21	81	2.37	— 0.3	13	11,043	ne.	53	se.	6	3	18	10	6.3	20.1	....
Cleveland	762	190	201	29.12	29.97	— .06	30.1	— 4.1	75	25	38	6	18	22	34	27	23	79	2.29	— 0.5	16	10,593	nw.	56	sw.	9	6	10	15	6.4	15.7	....
Sandusky	629	62	103	29.26	29.96	— .07	30.0	— 5.2	77	25	38	9	16	22	40	27	24	81	3.09	+ 0.5	15	10,426	nw.	48	n.	22	7	10	14	6.3	16.1	....
Toledo	628	208	243	29.28	29.98	— .05	30.4	— 4.4	71	25	39	7	17	22	35	27	23	79	4.41	+ 2.1	15	11,339	n.	57	sw.	9	11	8	12	5.3	17.1	....
Fort Wayne	856	113	124	29.03	29.98	.....	33.0	— 5.9	73	25	42	5	4	24	31	29	25	77	2.06	.....	11	8,025	ne.	46	sw.	9	7	8	16	6.4	3.3	....
Detroit	730	218	245	29.16	29.98	—. 05	28.7	— 4.2	59	31	37	7	23	20	30	26	23	82	3.92	+ 1.6	16	7,875	n.	37	n.	22	11	9	11	5.6	21.0	....
Upper Lake Region.							23.7	— 3.9										80	2.68	+ 0.4													6.2		
Alpena	609	13	92	29.31	30.00	— .03	20.3	— 4.7	47	29	28	— 5	1	12	29	19	16	83	3.46	+ 1.4	16	8,884	nw.	47	se.	6	8	9	14	6.1	16.8	T.
Escanaba	612	54	60	29.33	30.03	— .01	19.5	— 4.0	46	30	28	—10	17	11	33	17	13	78	3.05	+ 1.1	12	7,513	n.	39	n.	22	12	7	12	4.8	32.4	1.0
Grand Haven	632	54	92	29.28	29.99	— .04	27.8	— 3.0	70	25	36	5	17	20	30	25	21	76	2.59	+ 0.1	14	9,261	n.	43	sw	9	5	13	13	6.2	7.3	....
Grand Rapids	707	70	87	29.20	30.00	— .03	28.8	— 4.2	68	25	37	5	17	20	29	26	22	77	3.16	+ 0.6	15	5,381	ne.	26	nw.	9	6	12	13	6.4	15.9	....
Houghton	684	62	72	29.29	30.05	+ .01	17.6	— 6.2	46	28	26	—18	17	9	34	.....	.....	.....	2.56	+ 0.5	11	6,413	w.	34	e.	6	12	8	11	5.6	17.0	11.0
Lansing	878	11	62	29.00	29.98	.....	26.2	— 5.1	67	25	36	— 4	23	17	35	23	20	82	3.09	+ 0.8	18	5,908	ne.	31	nw.	9	4	9	18	6.9	19.3	....
Ludington	637	60	66	29.27	29.99	.....	25.7	.....	60	25	33	3	2	19	26	24	21	83	3.29	.....	18	8,662	n.	40	s.	4	7	8	16	6.4	15.9	....
Marquette	734	77	111	29.23	30.06	+ .02	19.6	— 4.1	47	25	27	— 6	1	12	28	17	13	76	3.36	+ 1.2	17	7,347	nw.	33	e.	6	8	7	16	6.5	31.2	15.0
Port Huron	638	70	120	29.26	29.97	— .06	24.5	— 5.1	54	31	32	1	3	17	29	22	20	84	2.14	— 0.3	15	9,681	nw.	48	nw.	4	3	17	11	6.4	15.5	T.
Saginaw	641	48	82	29.27	29.99	.....	24.6	.....	60	25	33	1	17	16	32	23	21	88	3.26	+ 0.6	13	7,982	nw.	38	w.	9	6	4	21	7.0	10.2	....
Sault Ste. Marie	614	11	61	29.31	30.04	+ .01	16.2	— 5.1	53	30	26	—16	17	6	37	14	10	78	2.01	+ 0.2	12	6,963	nw.	37	nw.	16	11	6	14	5.8	18.0	7.0
Chicago	823	140	310	29.08	29.99	— .04	34.6	+ 0.2	72	25	41	12	4	28	32	31	26	72	2.48	— 0.1	13	11,396	n.	48	ne.	22	7	9	15	6.6	5.5	....
Green Bay	617	109	144	29.32	30.01	— .03	23.8	— 3.0	54	31	32	— 2	17	16	36	21	16	75	1.53	— 0.9	12	9,118	n.	50	n.	22	6	12	13	6.7	12.0	....
Milwaukee	681	119	133	29.23	29.99	— .04	29.7	— 1.2	58	31	36	8	4	23	28	28	25	85	2.38	— 0.3	11	9,472	n.	40	n.	26	5	14	12	6.2	11.7	....
Duluth	1,133	11	47	28.78	30.05	— .01	18.9	— 5.2	45	29	27	— 9	2	11	31	17	14	82	2.48	+ 0.9	12	10,414	ne.	57	w.	9	14	6	11	4.7	23.3	2.5
North Dakota.							21.2	+ 0.3										84	1.67	+ 0.7													5.8		
Moorhead	940	8	57	29.01	30.07	— .01	20.8	— 0.6	49	31	30	—24	2	12	35	19	18	89	1.51	+ 0.4	9	7,362	se.	30	nw.	7	16	6	9	4.1	7.5	....
Bismarck	1,674	8	57	28.21	30.07	+ .01	24.7	+ 2.6	59	11	35	—23	2	15	34	22	18	80	3.27	+ 2.2	8	8,725	nw.	36	ne.	29	13	7	11	5.2	25.6	4.3
Devils Lake	1,482	11	44	28.40	30.05	.00	17.0	— 1.5	46	27	26	—27	1	8	35	16	14	88	1.09	+ 0.1	10	10,022	ne.	42	ne.	30	7	8	16	6.9	13.0	0.5
Williston	1,872	41	48	27.98	30.03	— .01	22.4	+ 0.8	51	11	31	—25	1	13	35	20	16	78	0.80	+ 0.1	5	6,850	se.	34	se.	15	4	13	14	6.9	5 5	T.
Upper Mississippi Valley.							36.5	+ 0.5										73	1.81	— 0.6													6.0		
Minneapolis	918	10	208	29.00	30.01	.....	26.0	.....	57	28	35	— 8	2	17	32	.....	.....	.....	1.19	— 0.5	8	9,040	nw.	43	nw.	9	10	8	13	6.1	5.6	T.
St. Paul	837	201	236	29.07	30.02	— .03	26.2	— 2.0	55	29	35	— 7	2	17	30	.....	.....	.....	1.26	— 0.3	9	9,181	nw.	48	nw.	9	10	9	12	5.8	6.5	T.
La Crosse	714	11	48	29.21	30.00	— .04	31.6	+ 0.7	60	30	40	3	3	23	31	.....	.....	.....	1.03	— 0.6	11	4,891	nw.	28	w.	9	8	9	14	6.2	1.9	....
Madison	974	70	78	28.93	30.02	— .02	28.6	— 1.5	60	31	37	5	4	20	32	26	21	76	2.93	+ 0.7	11	9,080	n.	46	n.	22	5	10	16	7.1	14.3	....
Charles City	1,015	10	49	28.89	30.00	— .05	31.0	+ 2.6	63	24	41	0	3	21	36	27	24	81	1.49	— 0.4	9	6,230	se.	26	w.	9	6	12	13	6.4	7.9	....
Davenport	606	71	79	29.31	29.98	— .05	35.8	+ 0.4	72	24	45	9	3	27	35	32	27	74	2.47	+ 0.3	10	6,702	e.	33	e.	21	9	5	17	6.5	3.8	....
Des Moines	861	84	97	29.04	29.97	— .07	37.6	+ 1.9	77	12	48	5	3	27	42	33	28	73	0.60	— 1.0	10	7,081	n.	32	sw	24	6	10	15	6.4	1.3	....
Dubuque	698	81	96	29.25	30.02	— .02	33.6	+ 0.4	66	12	42	6	3	25	35	29	24	71	3.91	+ 1.7	11	6,076	n.	27	nw.	9	4	10	17	7.0	8.9	....
Keokuk	614	64	78	29.28	29.97	— .06	39.3	+ 1.4	77	24	49	9	3	30	37	35	31	77	1.37	— 1.0	9	6,973	n.	36	w.	7	11	15	5	4.6	1.6	....
Cairo	356	87	93	29.58	29.98	— .06	46.5	— 0.5	78	21	56	22	4	37	42	41	36	69	1.65	— 2.4	11	8,904	s.	41	n.	14	8	12	11	5.9	0.5	....
Peoria	609	11	45	29.31	29.98	— .05	37.4	+ 0.4	73	24	47	9	4	28	34	33	30	81	2.33	— 0.6	7	7,032	n.	34	ne.	22	10	8	13	5.5	4.0	....
Springfield, Ill	644	10	91	29.27	29.97	— .06	39.8	+ 0.7	76	24	50	9	4	30	44	35	30	74	1.89	— 1.2	7	7,936	e.	33	w.	7	9	8	14	6.3	7.7	....
Hannibal	534	74	109	29.37	29.96	— .06	41.8	+ 0.2	81	24	52	10	3	31	42	.....	.....	.....	1.44	— 1.3	10	8,384	n.	37	w.	22	12	8	11	5.5	6.5	....
St. Louis	567	265	303	29.34	29.96	— .07	45.0	+ 1.5	80	13	55	15	4	35	48	39	35	74	1.83	— 1.6	9	11,320	nw.	54	w.	22	12	8	11	5.4	9.4	....
Missouri Valley.							40.7	+ 4.6										71	1.46	— 0.5													5.3		
Columbia, Mo.	781	11	84	29.09	29.94	— .09	44.7	+ 3.3	86	21	56	12	3	33	40	.....	.....	.....	1.93	— 1.1	8	7,783	n.	40	w.	22	7	12	12	5.9	7.1	....
Kansas City	963	161	181	28.90	29.95	— .07	45.8	+ 5.0	89	21	56	6	3	35	38	39	33	66	4.46	+ 1.6	9	10,524	n.	60	w.	21	15	8	8	4.5	2.7	....
St. Joseph	967	11	49	28.90	29.96	.....	43.2	.....	88	21	55	4	3	32	41	36	30	67	2.98	.....	8	8,586	nw.	56	nw.	21	9	13	9	5.3	1.2	....
Springfield, Mo.	1,324	98	104	28.54	29.96	— .06	47.8	+ 4.3	88	21	59	11	3	36	37	40	34	66	2.42	— 1.6	10	10,562	se.	49	nw.	22	16	7	8	3.9	3.8	....
Iola	984	11	50	28.88	29.94	— .07	47.1	+ 4.7	93	21	60	4	3	34	45	.....	.....	.....	2.10	— 0.2	10	7,065	n.	39	nw.	22	15	7	9	4.0	1.9	....
Topeka	983	85	101	.....	.....	.....	45.9	+ 5.0	91	21	58	1	3	33	45	.....	.....	.....	2.55	+ 0.3	10	8,834	n.	48	nw.	22	11	10	10	5.3	3.4	....
Drexel	1,299	10	53	28.56	29.98	.....	37.8	.....	74	12	49	— 2	3	26	37	33	29	81	0.63	.....	7	10,087	se.	46	nw.	22	4	18	9	6.1	1.5	....
Lincoln	1,189	11	84	28.68	29.97	— .05	41.2	+ 5.2	81	12	53	— 1	3	29	42	34	28	68	0.99	— 0.3	6	9,676	n.	54	nw.	22	11	11	9	5.0	1.2	....
Omaha	1,105	115	121	28.77	29.98	— .06	39.5	+ 3.5	73	12	50	1	2	29	36	34	28	67	0.35	— 1.0	7	8,052	nw.	38	nw.	7	12	11	8	5.0	1.0	....
Valentine	2,598	47	54	27.21	29.97	— .06	38.8	+ 6.9	77	28	52	—10	3	25	55	32	26	69	0.16	— 1.0	7	8,512	nw.	49	nw.	21	4	18	9	6.3	1.6	....
Sioux City	1,135	94	164	28.74	29.99	— .06	35.9	+ 3.3	70	12	46	— 8	2	26	41	31	27	75	0.70	— 0.6	6	10,373	n.	58	nw.	6	12	14	5	4.9	3.2	....
Huron	1,306	59	74	28.58	30.02	— .04	31.6	+ 4.9	69	28	42	—15	2	22	36	28	24	78	0.89	— 0.1	6	9,631	se.	39	nw.	6	4	13	14	6.7	4.5	....
Pierre	1,572	70	75	28.29	30.00	— .05	34.6	+ 5.1	76	27	47	—10	2	22	44	29	23	69	0.38	— 1.0	5	8,094	nw.	41	nw.	7	9	15	7	5.2	2.0	....
Yankton	1,233	49	57	28.62	29.98	— .07	35.4	+ 4.2	68	28	46	—12	2	25	41	.....	.....	.....	0.65	— 0.5	10	7,153	nw.	38	nw.	7	5	11	15	6.6	3.7	....

TABLE I.—*Climatological data for Weather Bureau stations, March, 1916*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01" or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*		°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
Northern Slope.							**37.3**	**+ 6.5**											**62**	**0.93**	**− 0.2**									**5.9**		
Havre	2,505	11	44	27.27	29.96	− .04	34.0	+ 6.7	65	20	45	−17	1	23	35		30	26	77	0.59	+ 0.1	8	6,503	sw.	42	w.	27	7	14	10	5.6	3.8	....
Helena	4,110	87	114	25.73	29.97	− .04	38.6	+ 7.6	66	11	49	− 7	2	28	44		31	22	55	0.48	− 0.3	9	7,411	sw.	46	sw.	8	3	13	15	6.8	7.5	....
Kalispell	2,962	11	34	26.88	29.99	.00	35.4	+ 2.4	57	16	44	2	2	27	31		31	26	73	2.43	+ 1.4	17	3,478	sw.	34	sw.	12	5	11	15	7.1	8.2	....
Miles City	2,371	26	48	27.41	30.02	.00	37.7	+ 9.1	71	20	50	− 9	2	25	44		32	28	74	0.35	− 0.4	10	4,566	ne.	34	nw.	7	12	10	9	5.4	1.8	....
Rapid City	3,259	50	58	26.52	30.00	− .01	37.8	+ 6.2	73	27	51	−10	3	25	58		31	22	58	1.02	0.0	9	8,011	n.	48	n.	6	6	15	10	5.9	10.8	T.
Cheyenne	6,088	84	101	22.93	29.95	− .01	38.6	+ 5.6	67	20	50	3	2	27	39		30	19	49	0.20	− 0.8	4	15,770	w.	78	nw.	21	7	16	8	5.8	2.0	....
Lander	5,372	60	68	24.58	29.99	.00	38.5	+ 7.2	69	17	53	2	2	24	48		30	20	53	1.62	0.0	6	5,323	w.	58	w.	5	13	10	8	5.1	13.0	....
Sheridan	3,790	10	47	26.03	29.99	.....	38.0	.....	73	17	52	−15	3	24	67		30	21	59	0.92	.....	11	5,707	nw.	50	nw.	21	10	7	14	5.7	4.9	....
Yellowstone Park	6,200	11	48	23.81	30.02	.00	32.4	+ 5.9	57	18	41	− 7	2	24	30		27	21	64	1.46	− 0.7	14	9,169	s.	40	s.	5	6	12	13	6.6	10.7	T.
North Platte	2,821	11	51	27.02	29.98	− .02	43.0	+ 7.7	80	20	58	− 5	3	28	48		33	25	59	0.20	− 0.7	4	7,085	nw.	40	nw.	21	14	9	8	4.7	2.1	....
Middle Slope.							**48.3**	**+ 5.8**											**52**	**0.90**	**− 0.6**									**4.5**		
Denver	5,292	106	113	24.67	29.94	− 0.1	45.7	+ 7.0	75	12	59	7	2	33	41		34	19	41	0.52	− 0.5	3	7,317	w.	46	sw.	21	9	15	7	5.2	5.3	....
Pueblo	4,685	80	86	25.23	29.92	.00	48.5	+ 7.9	78	12	64	9	2	33	50		37	23	42	0.65	− 0.2	4	6,950	nw.	50	w.	21	18	10	3	3.4	1.8	....
Concordia	1,392	50	58	28.47	29.97	− .04	44.5	+ 3.8	86	21	58	− 3	3	31	44		36	29	62	0.37	− 1.1	4	7,782	nw.	52	nw.	21	5	15	11	6.2	3.3	....
Dodge	2,509	11	51	27.36	29.98	+ .01	48.1	+ 6.4	88	21	64	0	3	32	55		37	27	55	0.68	− 0.2	5	8,880	n.	44	s.	23	16	11	4	4.2	5.5	....
Wichita	1,358	139	158	28.48	29.93	− .06	48.7	+ 4.6	92	21	62	1	3	36	43		39	30	56	1.50	− 0.8	6	12,149	n.	50	w.	21	18	6	7	3.8	2.0	....
Oklahoma	1,214	10	47	28.67	29.95	− .03	54.4	+ 5.2	95	21	68	12	3	41	42		43	33	54	1.66	− 0.7	6	13,606	s.	50	n.	14	18	6	7	4.1	T.	....
Southern Slope.							**60.2**	**+ 7.1**											**37**	**0.78**	**− 0.1**									**2.8**		
Abilene	1,738	10	52	28.15	29.95	− .01	62.4	+ 7.5	98	21	77	22	3	48	44		46	28	35	1.18	− 0.2	2	9,744	s.	39	n.	14	12	15	4	4.1	.....	....
Amarillo	3,676	10	49	26.22	29.95	.00	53.7	+ 8.7	87	13	70	16	3	38	46		40	27	45	0.57	− 0.1	2	9,687	ne.	40	n.	25	28	2	1	2.8	4.0	1.5
Del Rio	944	64	71	28.98	29.96	+ .01	68.7	+ 7.0	95	24	83	44	27	54	36		.....	.....	.....	0.78	− 0.3	1	7,816	se.	50	nw.	24	27	3	1	1.9	.....	....
Roswell	3,566	75	85	26.34	29.93	+ .03	56.6	+ 5.3	87	12	72	27	3	41	48		41	21	30	0.58	+ 0.1	3	7,391	nw.	38	sw.	1	23	6	2	2.4	T.	....
Southern Plateau.							**53.0**	**+ 4.0**											**40**	**0.52**	**0.0**									**2.9**		
El Paso	3,762	110	133	26.18	29.92	+ .04	60.4	+ 4.5	86	12	74	35	25	47	40		44	23	30	0.34	0.0	3	9,848	w.	57	sw.	22	19	10	2	2.7	T.	....
Santa Fe	7,013	57	66	23.24	29.96	+ .07	43.6	+ 4.2	68	20	55	20	3	32	33		33	21	47	1.36	+ 0.6	9	7,233	n.	39	sw.	5	14	13	4	4.1	8.5	T.
Flagstaff	6,908	8	57	23.36	29.96	+ .05	40.0	+ 4.1	69	9	54	11	25	26	43		.....	.....	.....	1.77	.....	8	.....	w.	46	w.	23	16	12	3	.....	5.8	....
Phoenix	1,108	76	81	28.79	29.94	+ .03	64.0	+ 3.5	91	10	78	38	25	50	38		51	39	45	0.37	− 0.1	4	3,922	e.	31	w.	23	19	6	6	3.0	.....	....
Yuma	141	9	54	29.80	29.94	.00	69.8	+ 5.3	100	12	85	39	25	55	41		54	39	39	0.24	− 0.1	2	4,694	n.	40	w.	23	27	3	1	1.1	.....	....
Independence	3,910	11	42	26.02	29.99	+ .05	52.0	+ 2.4	80	10	68	26	6	36	44		.....	.....	.....	0.31	− 0.2	3	6,494	n.	45	nw.	1	18	10	3	3.4	.....	....
Middle Plateau.							**45.2**	**+ 4.2**											**51**	**1.13**	**− 0.1**									**3.8**		
Reno	4,532	74	81	25.50	30.05	+ .07	46.9	+ 5.9	79	9	61	20	24	33	45		36	24	47	0.33	− 0.9	5	5,672	w.	39	se.	4	15	11	5	3.5	3.1	....
Tonopah	6,090	12	20	24.09	30.03	.....	45.1	.....	69	9	56	16	24	35	32		35	23	46	0.57	− 0.8	1	8,433	se.	48	nw.	23	18	7	6	3.0	0.1	....
Winnemucca	4,344	18	56	25.64	30.06	+ .05	44.2	+ 4.6	75	11	59	18	24	30	46		36	26	58	0.62	− 0.3	6	6,035	sw.	35	nw.	5	14	7	10	4.7	2.2	....
Modena	5,479	10	43	24.63	30.01	+ .05	42.6	+ 3.4	72	12	58	3	2	27	46		34	23	53	1.50	+ 0.2	8	8,661	w.	48	nw.	21	18	9	4	3.1	5.5	....
Salt Lake City	4,360	147	189	25.63	30.03	+ .05	46.3	+ 4.9	73	17	56	23	6	36	30		38	28	51	3.03	+ 1.0	9	6,371	se.	53	nw.	5	14	7	10	4.8	16.0	....
Grand Junction	4,602	82	96	25.40	30.00	+ .06	45.8	+ 2.3	72	19	58	16	3	34	33		36	25	49	0.71	0.0	7	5,689	nw.	36	se.	23	17	6	8	3.9	6.9	....
Northern Plateau.							**43.8**	**+ 3.6**											**63**	**1.97**	**+ 0.4**									**7.3**		
Baker	3,471	48	53	26.44	30.06	+ .03	39.8	+ 4.3	63	16	49	20	1	30	32		35	30	70	0.89	− 0.6	11	5,588	se.	33	s.	3	6	11	14	6.3	5.7	....
Boise	2,739	78	86	27.19	30.07	+ .04	46.0	+ 3.8	72	16	56	25	2	36	31		38	27	52	0.71	− 0.7	8	5,388	se.	33	nw.	23	6	4	21	7.4	0.4	....
Lewiston	757	40	48	29.21	30.03	.00	46.4	+ 2.4	70	11	55	28	2	38	32		.....	.....	.....	1.77	+ 0.5	18	3,093	e.	26	w.	5	3	8	20	7.9	2.5	....
Pocatello	4,477	46	54	25.47	30.03	+ .02	41.6	+ 4.7	67	17	51	19	1	32	33		34	26	58	2.35	+ 0.6	10	8,330	se.	44	sw.	5	6	11	14	6.5	17.4	....
Spokane	1,929	101	110	27.93	30.01	.00	41.4	+ 2.5	64	11	49	19	2	34	29		37	32	71	2.62	+ 1.1	16	6,074	sw.	35	w.	12	0	12	19	8.1	8.6	....
Walla Walla	991	57	65	28.93	30.01	− .01	47.7	+ 3.7	70	10	56	31	5	40	26		42	36	65	3.46	+ 1.6	15	4,512	s.	31	sw.	20	4	8	19	7.4	4.5	....
North Pacific Coast Region.							**45.4**	**+ 0.6**											**81**	**9.45**	**+ 4.4**									**7.8**		
North Head	211	11	56	29.81	30.04	+ .03	45.0	+ 0.1	57	30	48	36	14	42	16		44	43	90	9.32	+ 4.1	23	15,465	s.	82	s.	21	2	8	21	7.9	.....	....
Port Crescent	259	8	53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Seattle	125	215	250	29.91	30.04	+ .05	44.4	+ 0.2	63	10	50	32	4	39	21		41	38	80	5.45	+ 1.8	19	9,526	s.	49	sw.	12	1	6	24	8.4	1.2	....
Pacoma	213	113	120	29.81	30.04	+ .04	44.4	+ 0.2	64	10	50	30	4	38	23		42	38	81	8.23	+ 4.2	20	5,450	sw.	28	sw.	5	0	9	22	8.4	T.	....
Tatoosh Island	109	7	57	29.86	29.96	.00	43.2	+ 0.3	52	10	47	34	4	40	11		41	39	86	18.16	+ 9.6	26	14,332	s.	62	s.	5	3	4	24	7.9	0.2	....
Tortland, Oreg	153	68	106	29.89	30.05	+ .03	47.0	+ 0.7	68	30	53	32	4	41	28		44	39	76	10.57	+ 5.4	21	5,493	s.	29	s.	5	1	7	23	8.2	1.9	....
Roseburg	510	9	57	29.54	30.10	+ .06	48.4	+ 1.8	72	30	58	30	24	39	37		44	39	72	4.95	+ 1.0	15	2,667	s.	20	s.	2	5	15	11	6.2	2.0	....
Middle Pacific Coast Region.							**53.6**	**+ 2.3**											**70**	**1.82**	**− 2.4**									**4.2**		
Eureka	62	73	89	30.07	30.14	+ .08	48.6	+ 0.6	64	30	54	34	24	43	22		46	44	84	4.83	− 2.1	14	5,929	s.	35	w.	1	8	5	18	6.8	.....	....
Mount Tamalpais	2,375	11	18	27.62	30.10	+ .04	49.8	+ 2.7	72	14	56	31	5	44	18		44	37	68	1.32	− 3.8	12	13,597	nw.	63	nw.	23	16	6	9	4.1	T.	....
Point Reyes Light	490	7	18	29.54	30.06	.....	52.1	+ 2.5	76	14	58	39	23	46	27		.....	.....	.....	0.78	.....	9	15,945	nw	81	nw.	23	14	10	7	4.7	.....	....
Red Bluff	332	50	56	29.71	30.07	+ .03	56.4	+ 2.6	89	10	67	34	2	46	37		48	40	60	1.25	− 2.5	7	4,681	nw.	25	se.	4	17	6	8	3.7	.....	....
Sacramento	69	106	117	30.01	30.08	+ .05	56.6	+ 2.4	79	11	66	37	24	47	27		50	44	67	1.06	− 2.0	5	5,666	s.	40	se.	4	19	10	2	2.6	.....	....
San Francisco	155	209	213	29.93	30.10	+ .04	56.6	+ 3.9	77	13	64	44	24	49	27		50	46	71	1.33	− 1.8	6	5,586	nw.	30	ne.	30	18	4	9	3.6	.....	....
San Jose	141	12	110	29.94	30.09	.....	55.0	+ 1.3	81	11	66	33	24	44	37		.....	.....	.....	1.10	− 1.9	8	4,206	nw.	28	se.	4	17	6	8	3.7	.....	....
South Pacific Coast Region.							**59.1**	**+ 4.0**											**72**	**1.45**	**− 1.2**									**3.5**		
Fresno	327	89	98	29.73	30.09	+ .08	57.4	+ 2.5	86	11	68	35	24	46	36		52	47	71	1.81	0.0	7	4,493	nw.	44	nw.	23	20	6	5	3.1	0.1	....
Los Angeles	338	159	191	29.65	30.02	.00	62.0	+ 6.4	96	10	72	45	23	52	31		53	46	65	0.90	− 2.1	4	4,365	sw	24	w.	23	16	7	8	3.8	.....	....
San Diego	87	62	70	29.93	30.02	.00	59.2	+ 3.0	81	8	66	43	25	52	28		54	50	78	0.98	− 0.7	6	4,727	nw.	46	w.	23	16	9	6	3.9	.....	....
San Luis Obispo	201	32	40	29.88	30.10	+ .04	57.9	+ 4.1	91	10	69	37	3	47	38		52	48	75	2.12	− 1.9	8	3,547	nw.	25	w.	28	20	4	7	3.3	.....	....
West Indies.																																
San Juan, P. R	82	8	54	29.93	30.02	.00	74.7	.....	83	10	80	65	28	70	15		.....	.....	.....	0.47	− 2.7	8	10,092	ne.	37	n.	18	15	13	3	3.4	.....	....
Panama.																																
Balboa Heights	118	7	97	29.76	29.88	.....	80.4	.....	91	13	89	69	6	72	20		73	71	81	0.89	+ 0.2	6	7,478	nw.	32	n.	17	0	27	4	6.1	.....	....
Colon	25	5	71	29.87	29.90	.....	80.5	.....	86	27	85	74	10	76	11		75	74	83	2.68	+ 1.0	19	10,929	n.	33	n.	19	16	13	2	3.9	.....	....

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during March, 1916, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	31–1 [1]			2.53														0.24			
Albany, N. Y	14–16			1.31														*			
Alpena, Mich	26–27			2.05														*			
Amarillo, Tex	31			0.40														*			
Anniston, Ala	25–26			1.26														.40			
Asheville, N. C	26–27			0.72														.19			
Atlanta, Ga	7	11:17 a. m.	12:50 p. m.	0.77	11:20 a. m.	11:54 a. m.	0.01	0.06	0.13	0.15	0.20	0.34	0.43	0.59							
Atlantic City, N. J	28–30			1.45														*			
Augusta, Ga	7			0.80														.58			
Baker, Oreg	22			0.38														*			
Baltimore, Md	27–29			1.59														.33			
Bentonville, Ark	25			0.65														.28			
Binghamton, N. Y	14–15			1.36														.11			
Birmingham, Ala	25–26			2.37														.45			
Bismarck, N. Dak	21			1.80														*			
Rock Island, R. I	22			0.45														.11			
Boise, Idaho	20			0.23														.18			
Boston, Mass	6–7			0.68														*			
Buffalo, N. Y	27–28			0.65														*			
Burlington, Vt	8–9			0.74														*			
Cairo, Ill	1			0.73														*			
Canton, N. Y	8–9			0.44														*			
Charles City, Iowa	21–22			0.93														*			
Charleston, S. C	2–3	11:30 p. m.	6:55 a. m.	1.05	6:05 a. m.	6:14 a. m.	.48	.37	.50												
Charlotte, N. C	3			0.30														.20			
Chattanooga, Tenn	25–26			1.13														*			
Cheyenne, Wyo	24			0.11														*			
Chicago, Ill	26–27			1.21														*			
Cincinnati, Ohio	26–27			0.86														.35			
Cleveland, Ohio	27			0.33														.16			
Columbia, Mo	25–27			1.05														.20			
Columbia, S. C	1–2			0.84														.58			
Columbus, Ohio	26–27			2.06														.42			
Concord, N. H	8			0.79														*			
Concordia, Kans	2			0.19														*			
Corpus Christi, Tex	0			0.00														0			
Davenport, Iowa	26			1.35														*			
Dayton, Ohio	26–27	5:25 p. m.	5:35 a. m.	1.56	5:53 p. m.	6:00 p. m.	.12	.30	.33												
Del Rio, Tex	31–1 [1]			0.85														.33			
Denver, Colo	24			0.35														*			
Des Moines, Iowa	25			0.19														.11			
Detroit, Mich	21–22			1.05														*			
Devils Lake, N. Dak	28–29			0.46														*			
Dodge City, Kans	25–26			0.31														*			
Dubuque, Iowa	25	D. N. a. m.	2:20 p. m.	0.70	5:46 a. m.	5:56 a. m.	.32	.18	.31												
Duluth, Minn	4–6			0.94														*			
Durango, Colo																		*			
Eastport, Me	15–16			0.59														.54			
Elkins, W. Va	22			1.28														.06			
El Paso, Tex	31–1 [1]			0.45														*			
Erie, Pa	22			0.75														*			
Escanaba, Mich	6			1.42														.32			
Eureka, Cal	4–6			1.77														*			
Evansville, Ind																		*			
Flagstaff, Ariz	22–24			0.88														.18			
Fort Smith, Ark	25			0.32														*			
Fort Wayne, Ind	26–27			0.84																	
Fort Worth, Tex	31–1 [1]	2:49 p. m.	10:55 a. m.	3.93	8:22 p. m.	8:50 p. m.	.30	.06	.13	.33	.48	.60	.63								
Fresno, Cal	19–20			0.72														.17			
Galveston, Tex	25			0.24														.17			
Grand Haven, Mich	26–28			1.64														*			
Grand Junction, Colo	1–2			0.32														*			
Grand Rapids, Mich	26–27			1.68														.28			
Green Bay, Wis	25–26			0.51														*			
Hannibal, Mo	26–27			0.80														.25			
Harrisburg, Pa	27–30			1.51														*			
Hartford, Conn	6–7			0.73														*			
Hatteras, N. C	2			1.08														*			
Havre, Mont	29			0.18														*			
Helena, Mont	27–29			0.25														*			
Houghton, Mich	6			0.57														*			
Houston, Tex	25			T.														T.			
Huron, S. Dak	23–24			0.44														*			
Independence, Cal	4			0.28														.05			
Indianapolis, Ind	25			0.76														.36			
Iola, Kans	24–25			0.95														.26			
Jacksonville, Fla	7–8	10:30 p. m.	D. N. a. m.	0.47	10:53 p. m.	10:59 p. m.	.01	.27	.29												
Kalispell, Mont	4–5			0.70														*			
Kansas City, Mo	26			2.68														.37			
Keokuk, Iowa	26–27			0.72														*			
Key West, Fla	8			0.47														.35			
Knoxville, Tenn	26–27			0.90														*			
La Crosse, Wis	25			0.48														.23			
Lander, Wyo	23–24			0.98														*			
Lansing, Mich	26–28			1.44														*			
Lewiston, Idaho	8			0.68														*			
Lexington, Ky	26			1.15														.34			
Lincoln, Nebr	24–25			0.88														*			
Little Rock, Ark	25			1.11														.32			
Los Angeles, Cal	20			0.53														.17			
Louisville, Ky	26	1:48 p. m.	3:45 p. m.	0.78	2:04 p. m.	2:14 p. m.	.07	.30	.53												
Ludington, Mich	6–8			1.08														*			
Lynchburg, Va	27			0.53														.25			
Macon, Ga	7			0.90														.47			
Madison, Wis	21–22			1.20														*			
Marquette, Mich	5–7			1.89														*			
Memphis, Tenn	25–26			1.01														*			

[1] Apr. 1.

* Self-register not working.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during March, 1916, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		3 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Meridian, Miss.	25	1:30 p. m.	D. N. p. m.	2.27	3:15 p. m.	3:40 p. m.	0.17	0.14	0.28	0.44	0.61	0.74									
Miami, Fla.	8			0.27														0.17			
Milwaukee, Wis.	21–22			0.90														*			
Minneapolis, Minn.	23–24			0.34														*			
Mobile, Ala.	25–26			1.05														*			
Modena, Utah.	20–21			0.49														*			
Montgomery, Ala.	25–26	5:55 p. m.	D. N. a. m.	1.87	12:14 a. m.	12:46 a. m.	.32	.07	.13	.21	.42	.71	0.93	1.04							
Moorhead, Minn.	30			0.54														*			
Mount Tamalpais, Cal.	4			0.48														.09			
Nantucket, Mass.	3–4			1.19														*			
Nashville, Tenn.	1			0.60														.51			
New Haven, Conn.	6–7			0.91														*			
New Orleans, La.	15			0.30														.30			
New York, N. Y.	6–7			0.96														.21			
Norfolk, Va.	3			0.42														.20			
Northfield, Vt.	8–9			0.58														*			
North Head, Wash.	7–9			3.36														*			
North Platte, Nebr.	2			0.08														*			
Oklahoma, Okla.	24	4:55 p. m.	9:10 p. m.	0.88	6:08 p. m.	6:20 p. m.	.05	.09	.30	.37											
Omaha, Nebr.	25			0.20														*			
Oswego, N. Y.	6			0.31														*			
Palestine, Tex.	25			0.47														.33			
Parkersburg, W. Va.	27–28			1.77														.29			
Pensacola, Fla.	26			0.22														.10			
Peoria, Ill.	26			1.01														.34			
Philadelphia, Pa.	28–30			1.43														*			
Phoenix, Ariz.	22			0.20														.20			
Pierre, S. Dak.	21			0.19														*			
Pittsburgh, Pa.	20–22			1.42														.25			
Pocatello, Idaho.	23–24			1.37														*			
Point Reyes Light, Cal.	3–4			0.47														.12			
Port Huron, Mich.	26–27			0.55														*			
Portland, Me.	8–9			1.28														.31			
Portland, Oreg.	24–25			2.85														*			
Providence, R. I.	6–7			0.65														*			
Pueblo, Colo.	13–14			0.45														*			
Raleigh, N. C.	1–2			0.59														.22			
Rapid City, S. Dak.	28–30			0.85														*			
Reading, Pa.	22			0.91														.29			
Red Bluff, Cal.	3–4			0.69														*			
Reno, Nev.	1			0.21														*			
Richmond, Va.	1–3			0.91														*			
Rochester, N. Y.	14–15			1.50														*			
Roseburg, Oreg.	3–6			2.97														*			
Roswell, N. Mex.	23			0.47														.18			
Sacramento, Cal.	4			0.75														.14			
Saginaw, Mich.	27–28			1.22														*			
St. Joseph, Mo.	24–25	9:25 p. m.	D. N. a. m.	1.53	10:02 p. m.	10:25 p. m.	.06	.16	.20	.40	.72	.81									
St. Louis, Mo.	25	6:59 a. m.	11:05 a. m.	0.53	6:59 a. m.	7:07 a. m.	.00	.21	.33												
St. Paul, Minn.	23–24			0.42														*			
Salt Lake City, Utah.	23–24			1.84														*			
San Antonio, Tex.	31–1[1]	10:37 p. m.	6:42 a. m.	1.18	10:53 p. m.	11:08 p. m.	.11	.18	.33	.49											
San Diego, Cal.	5			0.46														.13			
Sand Key, Fla.	8	12:21 p. m.	4:20 p. m.	0.53	12:27 p. m.	12:39 p. m.	.01	.30	.35	.38											
Sandusky, Ohio.	22			1.17														*			
San Francisco, Cal.	4			0.65														.17			
San Jose, Cal.	17			0.21														.16			
San Luis Obispo, Cal.	4–5			0.93														.27			
Santa Fe, N. Mex.	22–24			0.63														*			
Sault Ste. Marie, Mich.	6–7			0.71														*			
Savannah, Ga.	3			0.42														.35			
Scranton, Pa.	14–16			1.99														*			
Seattle, Wash.	19–20			1.06														.16			
Sheridan, Wyo.	28–30			0.61														*			
Shreveport, La.	25	4:00 a. m.	5:40 a. m.	1.35	4:06 a. m.	5:02 a. m.	.01	.14	.29	.46	.51	.67	.82	.93	1.05	1.15	1.21	1.33			
Sioux City, Iowa.	25			0.31														*			
Spokane, Wash.	21–22			0.53														*			
Springfield, Ill.	26–27			1.00														.36			
Springfield, Mo.	25			0.76														.36			
Syracuse, N. Y.	14–15			1.06														*			
Tacoma, Wash.	24–26			2.35														.22			
Tampa, Fla.	3	9:54 a. m.	11:00 a. m.	0.62	10:03 a. m.	10:18 a. m.	.01	.31	.50	.58											
Tatoosh Island, Wash.	6–12			11.73														.47			
Taylor, Tex.	24–25			0.12														.08			
Terre Haute, Ind.	6			0.34														.34			
Thomasville, Ga.	2–3	(about) 12 midnt.	D. N. a. m.	0.51	12:10 a. m.	12:34 a. m.	.02	.08	.12	.26	.38	.47									
Toledo, Ohio.	22			1.50														*			
Tonopah, Nev.	20			0.57														.18			
Topeka, Kans.	24–26			1.69														.34			
Valentine, Nebr.	2			0.04														*			
Vicksburg, Miss.	25	10:50 a. m.	2:10 p. m.	1.46	11:00 a. m.	11:22 a. m.	.02	.11	.37	.60	.73	.77									
Walla Walla, Wash.	3–5			1.23														*			
Washington, D. C.	27–29			1.12														*			
Wichita, Kans.	24			0.90														*			
Williston, N. Dak.	23–24			0.45														*			
Wilmington, N. C.	2			0.73														.44			
Winnemucca, Nev.	20			0.47														.13			
Wytheville, Va.	26–27			1.21														.40			
Yankton, S. Dak.	1			0.26														*			
Yellowstone Park, Wyo.	22–23			0.53														*			

* Self-register not working. † Record partly estimated. ‡ No precipitation occurred during month. [1] Apr. 1.

TABLE III.—*Data furnished by the Canadian Meteorological Service, March, 1916.*

Stations.	Altitude above M. S. L.* Jan. 1, 1916.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea-level reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.51	29.65	−0.23	25.4	−2.3	31.2	19.7	41	5	4.72	−0.04	17.0
Sydney, C. B. I.	48	29.69	*29.73*	− .15	23.6	−2.6	32.1	15.1	51	− 6	4.10	−0.83	33.0
Halifax, N. S.	88	29.63	*29.74*	− .20	25.7	−3.3	33.9	17.6	54	− 2	3.12	−2.34	31.2
Yarmouth, N. S.	65	29.70	29.77	− .18	26.2	−4.6	31.9	20.6	52	5	5.42	+0.57	53.4
Charlottetown, P. E. I.	38	29.70	29.74	− .16	19.8	−5.6	26.8	12.8	45	− 8	2.59	−0.62	25.9
Chatham, N. B.	28	29.80	*29.83*	− .07	19.4	−3.6	29.7	9.2	59	−12	1.59	−1.88	15.5
Father Point, Que.	20	29.86	29.89	− .01	16.1	−4.2	23.4	8.9	46	− 7	0.77	−1.96	7.7
Quebec, Que.	296	29.58	29.92	− .04	16.4	−4.8	24.5	8.4	48	− 9	1.20	−2.06	12.0
Montreal, Que.	187	29.72	29.94	− .06	20.3	−3.5	27.1	13.5	53	− 7	2.36	−1.43	22.8
Stonecliffe, Ont.	489	29.30	*29.93*	−. 08	16.1	−2.9	30.1	2.2	59	−28	1.28	−0.78	9.6
Ottawa, Ont.	236	29.68	29.96	− .05	18.0	−3.5	28.2	8.0	53	−16	2.32	−0.40	23.1
Kingston, Ont.	285	29.64	29.98	− .03	21.4	−4.2	30.1	12.7	54	−12	0.90	−1.74	5.3
Toronto, Ont.	379	29.54	*29.94*	− .08	25.4	−1.9	33.0	17.7	57	− 2	2.73	+0.09	18.6
White River, Ont.	1,244	28.63	*30.01*	− .02	7.8	−4.4	26.4	10.8	56	−49	1.88	+0.50	15.7
Port Stanley, Ont.	592	29.31	29.97	− .06	24.8	−2.4	29.6	12.6	49	− 9	3.71	+0.83	30.0
Southampton, Ont.	656	29.24			21.1	−3.6	29.6	12.6	49	− 9	3.71	+1.06	30.0
Parry Sound, Ont.	688	29.25	29.98	− .04	18.5	−2.6	29.0	8.0	56	−17	1.64	−0.59	14.9
Port Arthur, Ont.	644	29.32	30.05	.00	17.6	+0.8	28.9	6.4	48	−19	1.32	+0.35	10.4
Winnipeg, Man.	760	29.22	30.10	+ .01	14.8	+2.5	24.2	5.5	41	−26	2.13	+1.10	21.3
Minnedosa, Man.	1,690	28.18	30.09	+ .03	12.6	+0.1	22.8	2.4	43	−35	2.11	+1.46	21.1
Qu'Appelle, Sask.	2,115	27.68	30.03	− .01	15.1	+0.2	25.2	5.1	45	−30	2.24	+1.47	21.8
Medicine Hat, Alberta	2,144	27.57	*29.89*	− .11	32.1	+4.6	43.9	20.4	67	−20	0.29	−0.47	2.2
Swift Current, Sask.	2,392	27.30	*29.96*	− .06	23.9	+1.9	33.8	14.1	56	−26	1.88	+1.07	18.8
Calgary, Alberta	3,428	26.30	*29.92*	− .03	30.1	+3.9	43.1	17.2	64	−12	0.76	+0.04	6.8
Banff, Alberta	4,521	25.22	*29.92*	− .02	27.0	+6.8	37.1	17.0	51	−22	1.57	+0.16	14.9
Edmonton, Alberta	2,150	27.59	*29.95*	− .01	22.1	−2.1	33.0	11.3	57	−20	0.80	+0.08	7.8
Prince Albert, Sask.	1,450	28.42	*30.05*	− .03	15.0	+3.0	27.2	2.7	50	−32	0.98	+0.21	9.8
Battleford, Sask.	1,592												
Kamloops, B. C.	1,262	28.65	29.96	+ .04	40.0	+3.9	48.9	31.1	64	15	0.46	−0.11	0.5
Victoria, B. C.	230	29.72	29.98	+ .01	42.6	+0.7	47.3	37.8	58	31	5.37	+2.25	0.2
Barkerville, B. C.	4,180	25.50	29.86	− .02	26.7	+0.6	34.9	18.6	54	0	3.61	+1.72	24.0
Hamilton, Bermuda	151												

*The altitudes given above were furnished by the Director of the Canadian Meteorological Service, Mar. 9, 1916, and refer to cisterns of barometers at the respective stations. Where sea-level pressures and departures are *italicized* new reduction factors are in course of computation.—C. A., jr.

40278—16——5

Chart I. Hydrographs of Several Principal Rivers, March, 1916.

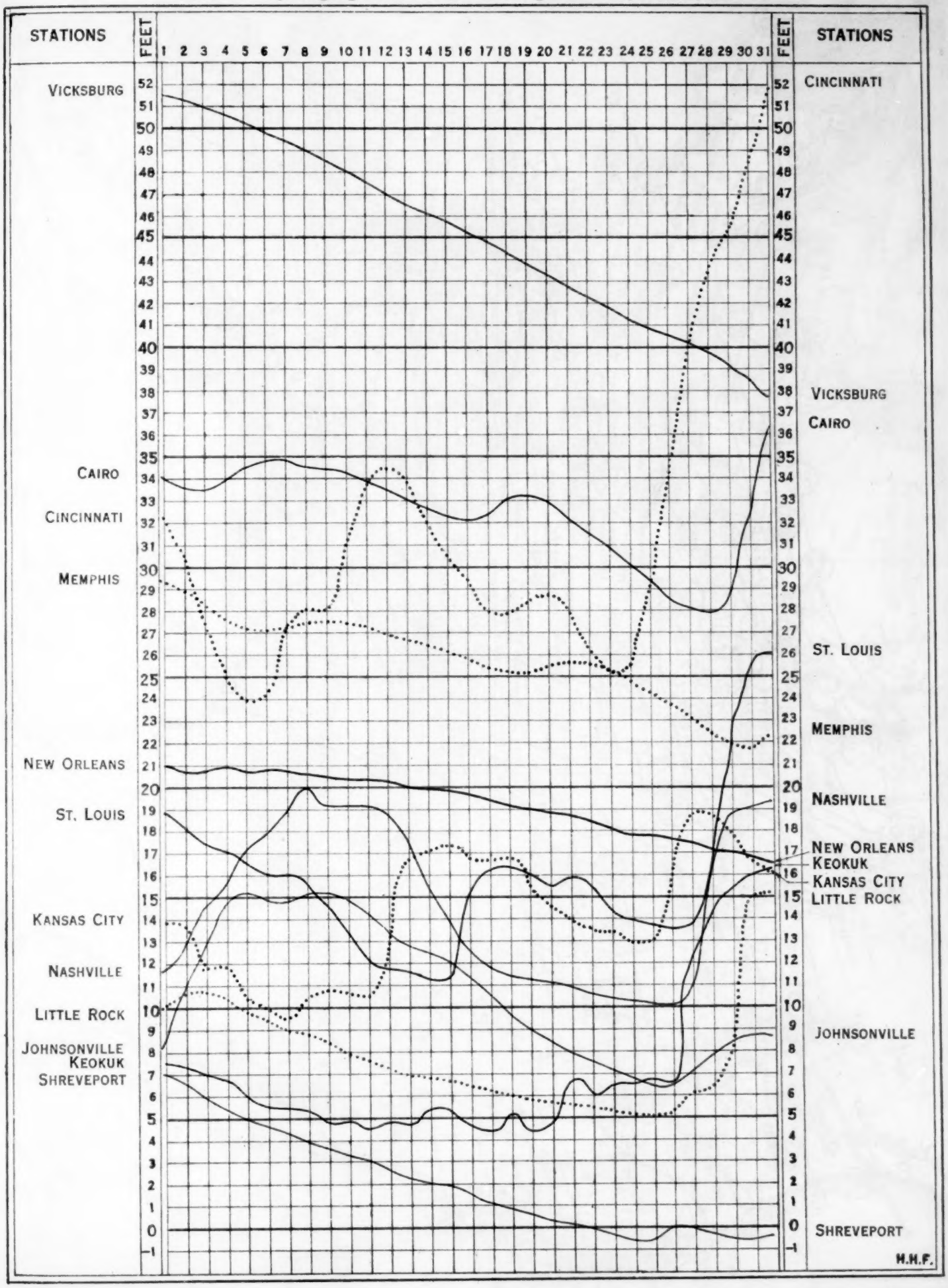


Chart II. Tracks of Centers of High Areas, March, 1916.

(Plotted by R. H. Weightman.)

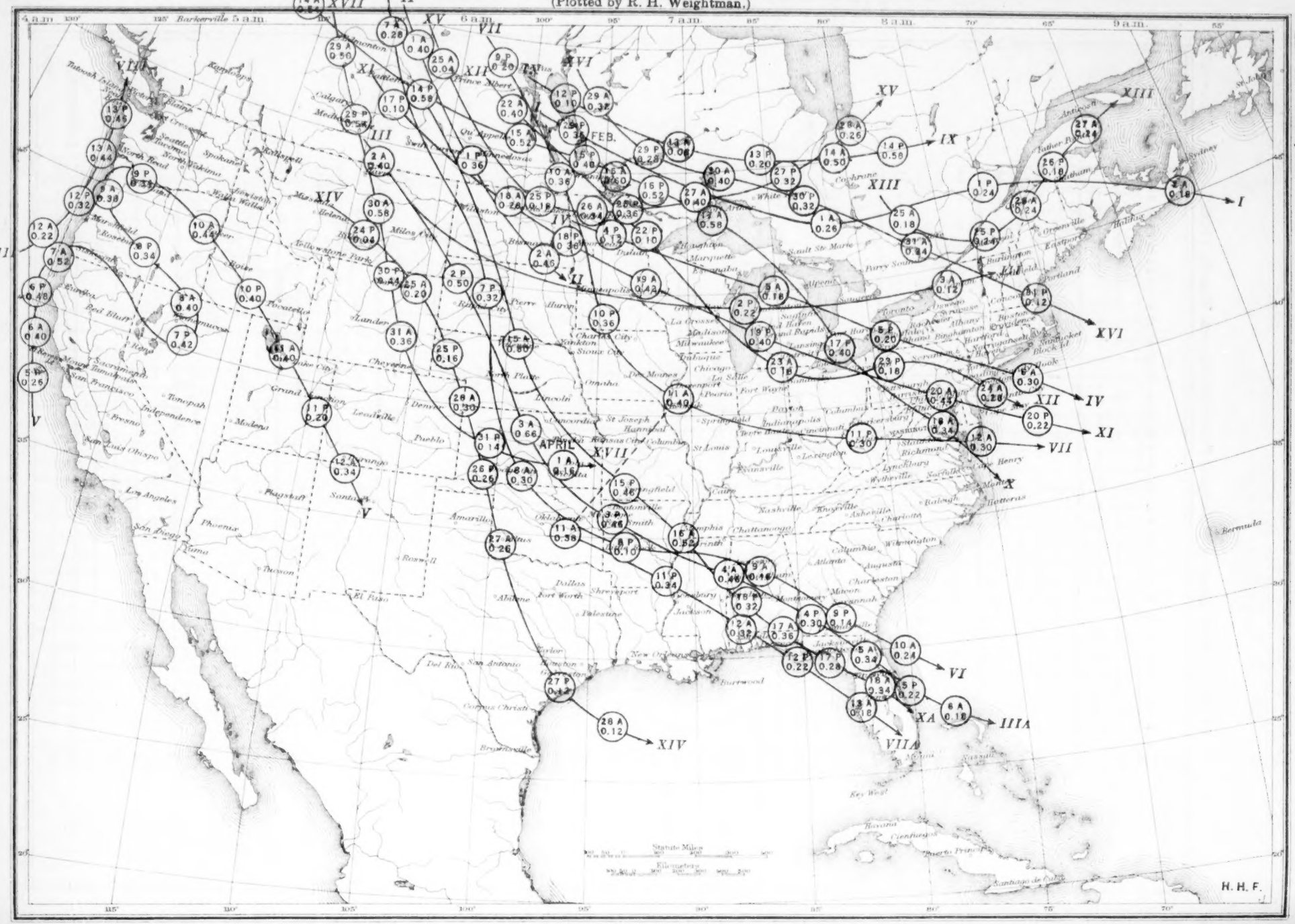


Chart III. Tracks of Centers of Low Areas, March, 1916.

Chart III. Tracks of Centers of Low Areas, March, 1916.

(Plotted by R. H. Weightman.)

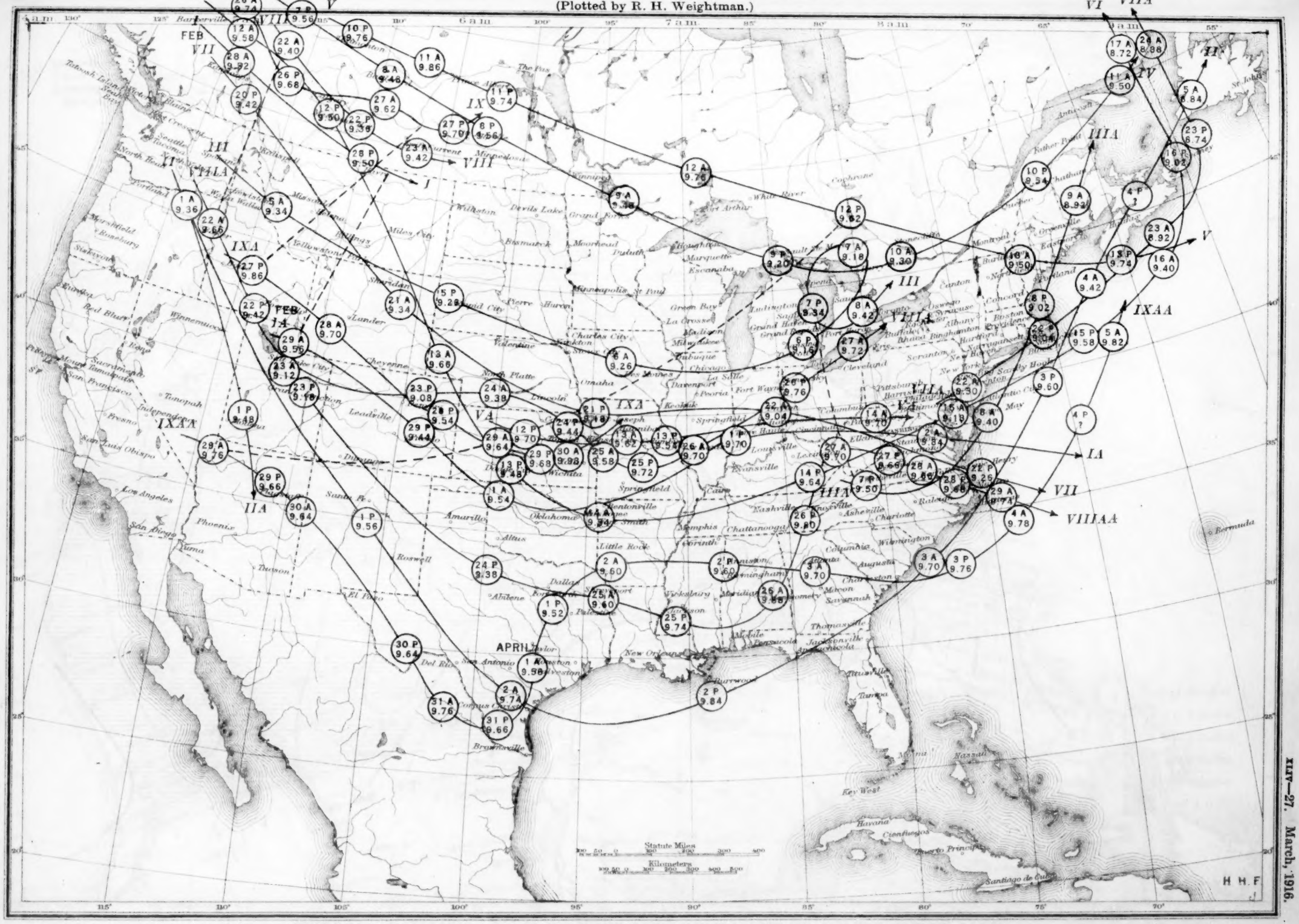


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, March, 1916.

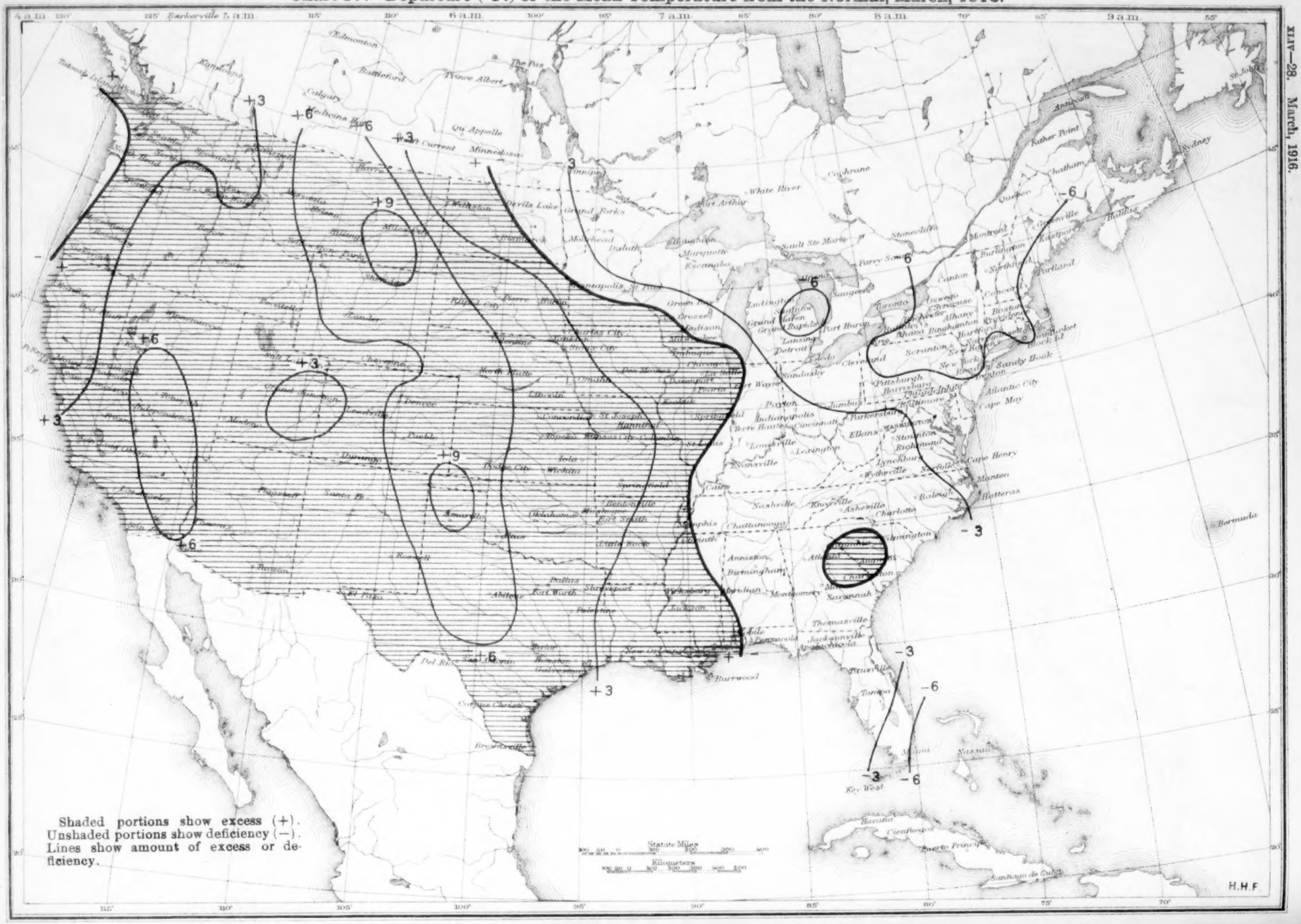


Chart V. Total Precipitation, March, 1916.

Chart V. Total Precipitation, March, 1916.

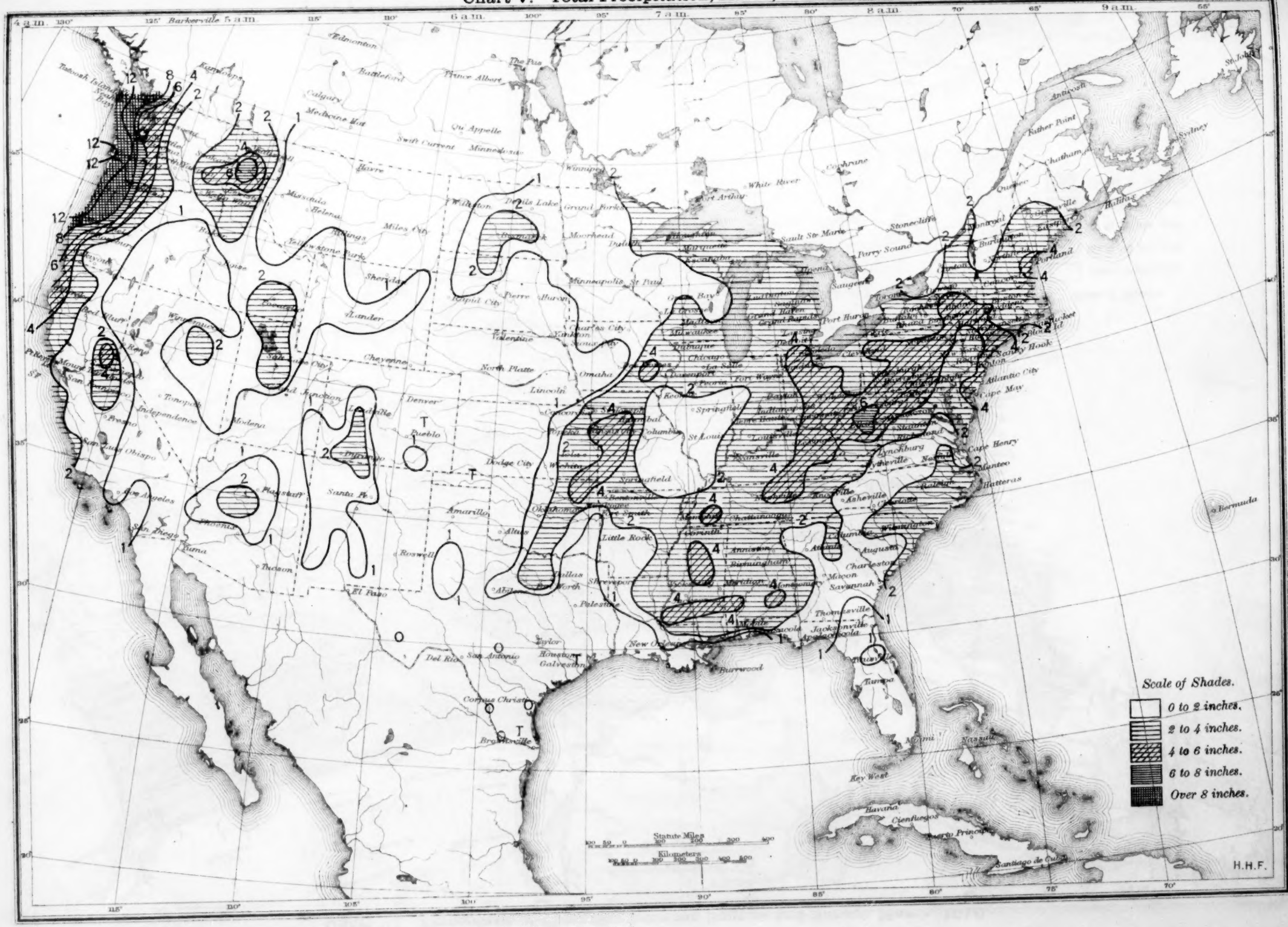


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, March, 1916.

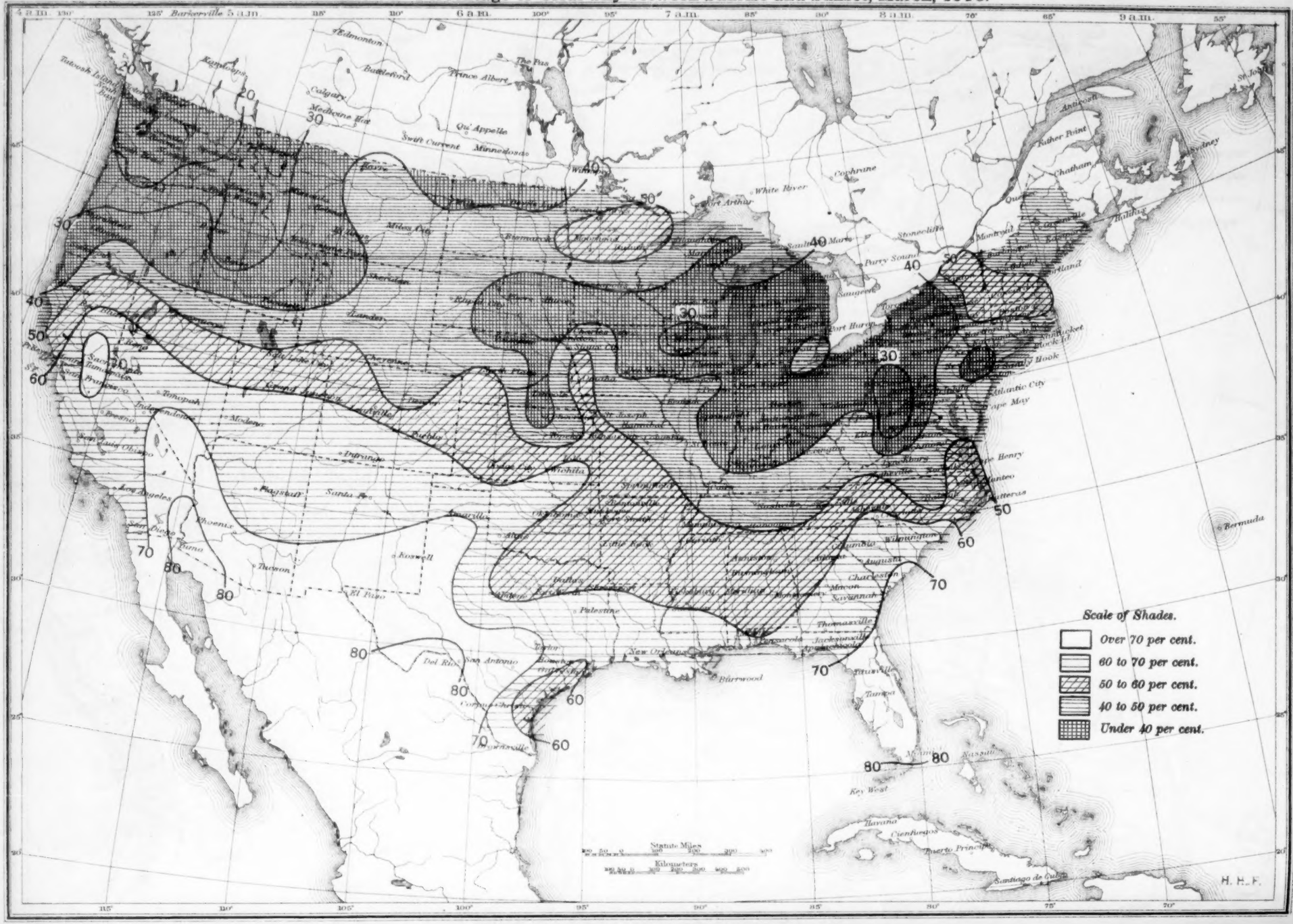
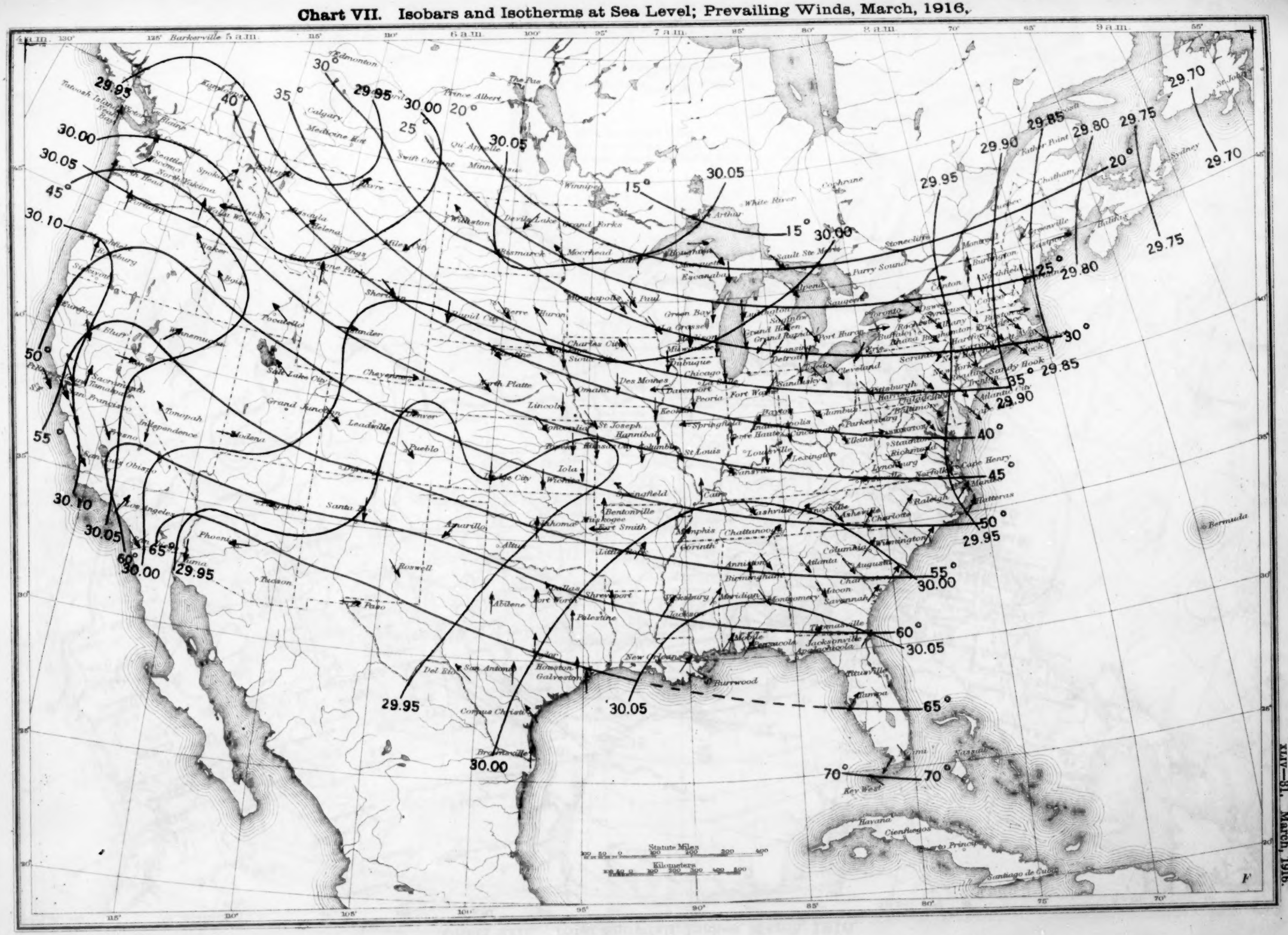


Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, March, 1916.

Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, March, 1916.


Barkerville
Edmonton
The Pas
Prince Albert
Calgary
Medicine Hat
Swift Current
Qu'Appelle
Minnedosa
Winnipeg
White River
Cochrane
Arthur
Stonecliffe
Sault Ste Marie
Parry Sound
Toronto
Kingston
Ottawa
Montreal
Quebec
Father Point
Chatham
Sydney
St. John's
Seattle
Tacoma
Spokane
North Yakima
Portland
Walla Walla
Baker
Boise
Helena
Billings
Miles City
Williston
Devils Lake
Grand Forks
Bismarck
Moorhead
Minneapolis
St. Paul
Duluth
Green Bay
La Crosse
Milwaukee
Grand Haven
Port Huron
Detroit
Buffalo
Rochester
Albany
Boston
Hartford
New York
Erie
Cleveland
Toledo
Sandusky
Pittsburgh
Harrisburg
Philadelphia
Baltimore
Atlantic City
Sandy Hook
Trenton
Scranton
Binghamton
Syracuse
Utica
Rochester
Oswego
Kingston
Toronto
Parry Sound
Sault Ste Marie
Stonecliffe
Ottawa
Quebec
Father Point
Chatham
Sydney
St. John's
Bermuda
Havana
Cienfuegos
Nassau
Key West
Tampa
Jacksonville
Apalachicola
Tallahassee
Thomasville
Mobile
Pensacola
Montgomery
Meridian
Vicksburg
Jackson
Shreveport
Fort Worth
Abilene
Palestine
Galveston
Houston
San Antonio
Del Rio
Corpus Christi
Brownsville
Burrwood
New Orleans
Vicksburg
Memphis
Chattanooga
Knoxville
Asheville
Charlotte
Columbia
Augusta
Atlanta
Birmingham
Macon
Savannah
Charleston
Wilmington
Raleigh
Norfolk
Cape Henry
Lynchburg
Richmond
Hatteras
Lexington
Louisville
Cairo
Springfield
Bentonville
Fort Smith
Amarillo
Oklahoma
Altus
Roswell
Tucson
Phoenix
Yuma
Los Angeles
Santa Fe
Albuquerque
Tucumcari
Trinidad
Pueblo
Leadville
Denver
Grand Junction
Salt Lake City
Cheyenne
North Platte
Omaha
Lincoln
Des Moines
Davenport
Peoria
Rockford
Chicago
Dubuque
Sioux City
Yankton
Huron
Sherman
Rapid City
Miles City
Billings
Bismarck
Williston
Devils Lake
Grand Forks
Winnipeg
Swift Current
Qu'Appelle
Minnedosa
Prince Albert
The Pas
Edmonton
Calgary
Medicine Hat
Barkerville
Seattle
Tacoma
Spokane
North Yakima
Portland
Walla Walla
Baker
Boise
Helena
Billings
Miles City
Sherman
Rapid City
Huron
Yankton
Sioux City
Omaha
Lincoln
North Platte
Cheyenne
Denver
Grand Junction
Salt Lake City
Leadville
Pueblo
Trinidad
Albuquerque
Santa Fe
Tucumcari
Amarillo
Oklahoma
Altus
Roswell
Tucson
Phoenix
Yuma
Los Angeles
San Diego
San Francisco
Sacramento
Tamalpais
Independence
Fresno
Modena
Tonopah
Eureka
Red Bluff
Portland
Walla Walla
Baker
Boise
Helena
Billings
Miles City
Sherman
Rapid City
Huron
Yankton
Sioux City
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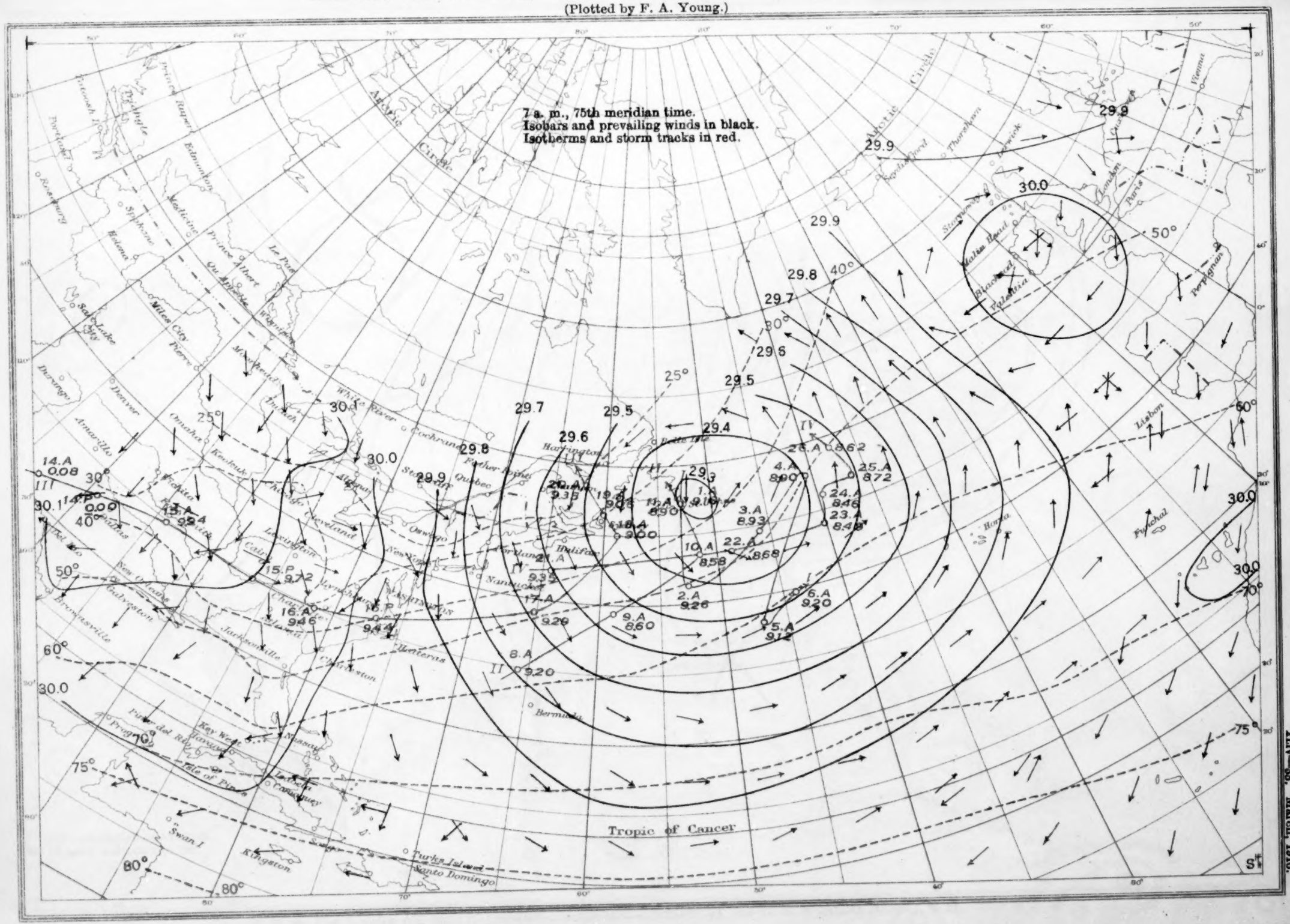
Tucumcari
Amarillo
Oklahoma
Altus
Roswell
Tucson
Phoenix
Yuma
Los Angeles
Santa Fe
Abilene
Fort Worth
Shreveport
Palestine
Galveston
Houston
San Antonio
Del Rio
Corpus Christi
Brownsville
Burrwood
New Orleans
Vicksburg
Memphis
Chattanooga
Knoxville
Asheville
Charlotte
Columbia
Augusta
Atlanta
Birmingham
Macon
Savannah
Charleston
Wilmington
Raleigh
Norfolk
Cape Henry
Lynchburg
Richmond
Hatteras
Lexington
Louisville
Cairo
Springfield
Bentonville
Fort Smith
Jackson
Meridian
Vicksburg
Jacksonville
Apalachicola
Tallahassee
Thomasville
Mobile
Pensacola
Montgomery
Havana
Cienfuegos
Nassau
Key West
Tampa
Jacksonville
Apalachicola
Tallahassee
Thomasville
Mobile
Pensacola
Montgomery
Meridian
Vicksburg
Jackson
Shreveport
Fort Worth
Abilene

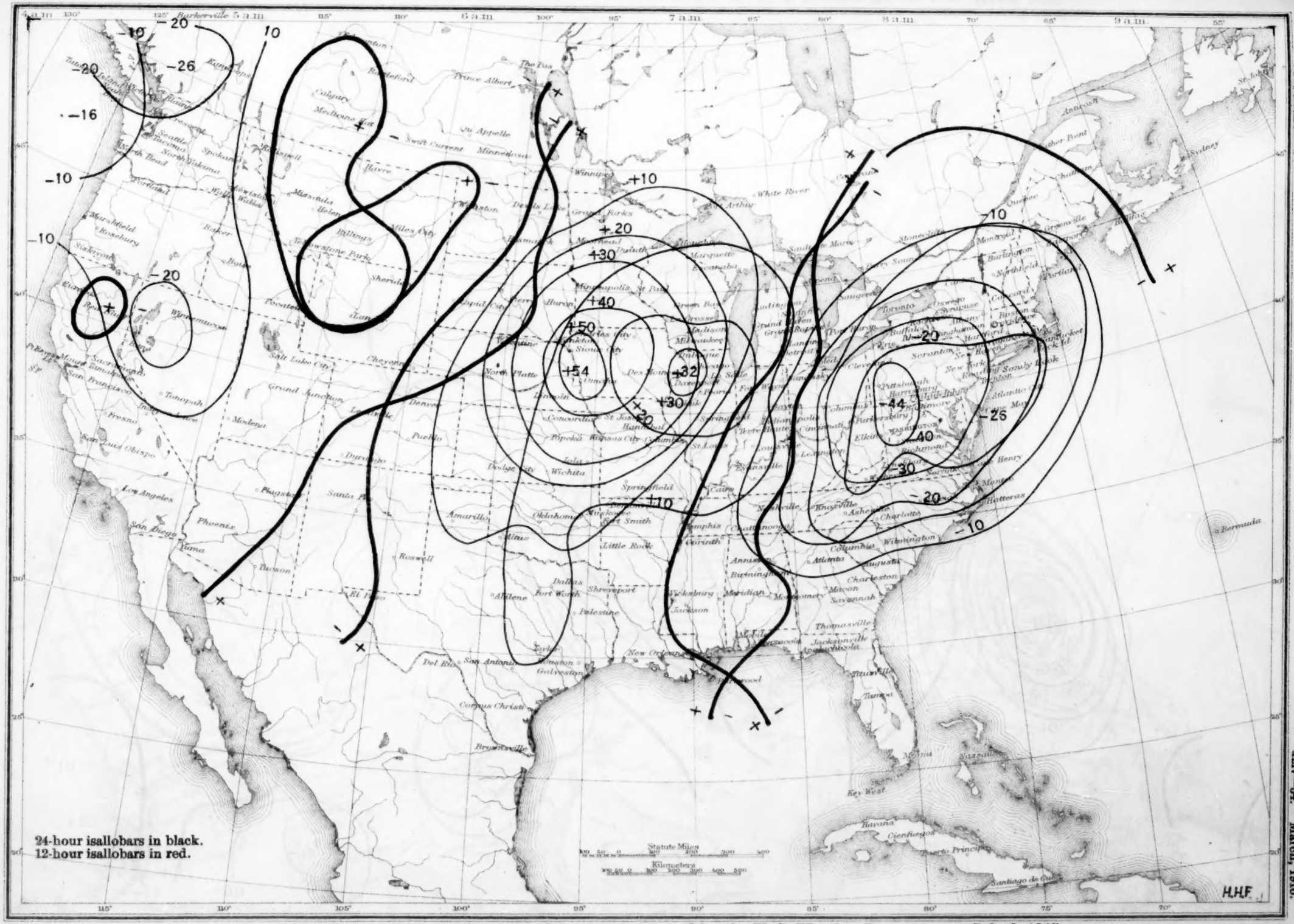
Chart VIII. Total Snowfall, Inches, March, 1916.

Chart IX. Means of Meteorological Data for North Atlantic Ocean, March, 1915.

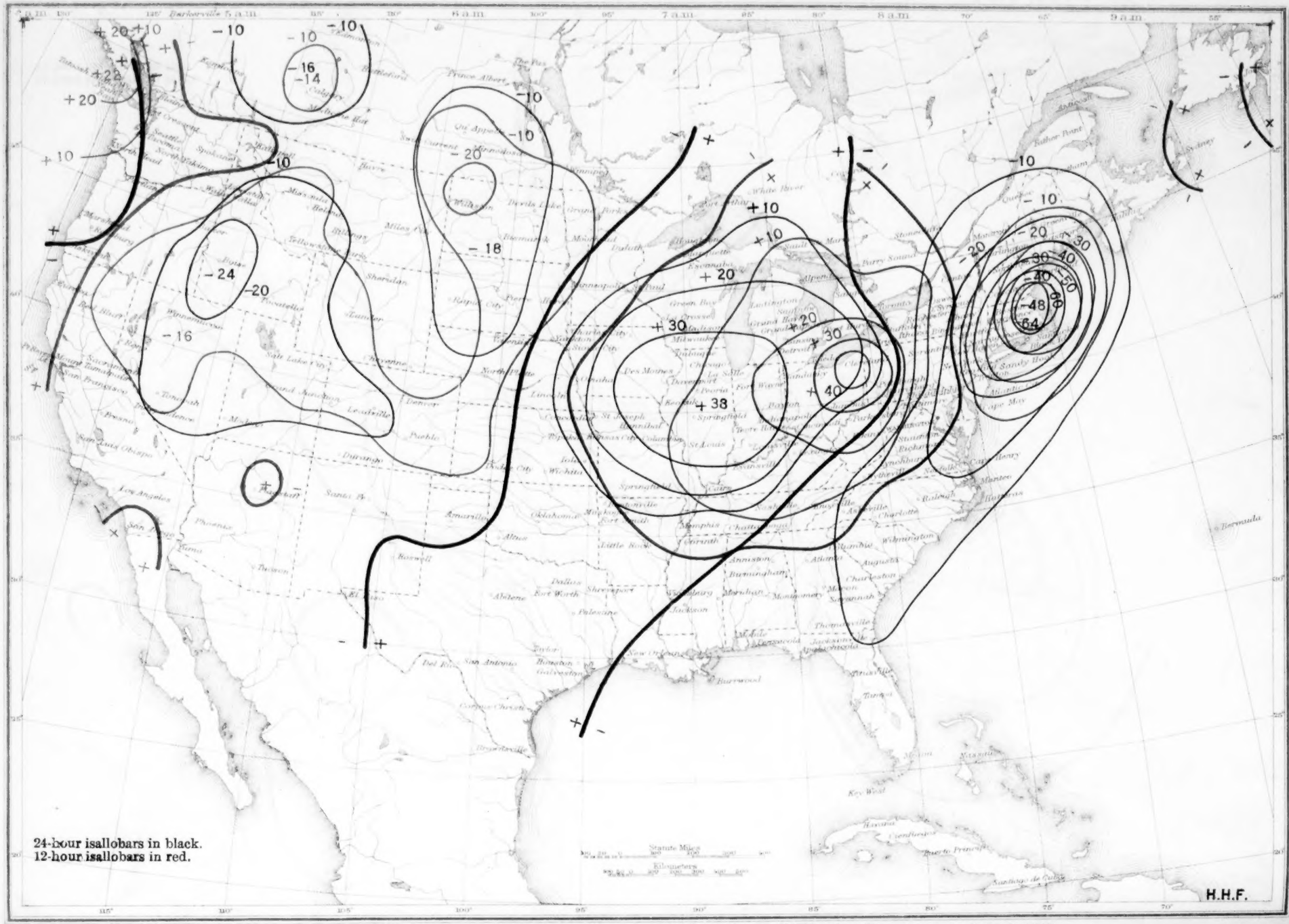
Chart IX. Means of Meteorological Data for North Atlantic Ocean, March, 1915.

(Plotted by F. A. Young.)


7 a. m., 75th meridian time.
Isobars and prevailing winds in black.
Isotherms and storm tracks in red.
Arctic Circle
Antarctic Circle
Tropic of Cancer
Bermuda
Halifax
Nantucket
Hatteras
Charleston
Jacksonville
Key West
Havana
Nassau
Turks Island
Santo Domingo
Kingston
Swan I
Isle of Pines
Progreso
Galveston
New Orleans
Denver
Omaha
Cleveland
Buffalo
Quebec
Father Point
Lisbon
Gibraltar
Madeira
Funchal
Horta
Malin Head
Blacksod
Valentia
Stornoway
Thurso
Reykjavik
Copenhagen
Paris
Perpignan
Vienna
Prince Rupert
Edmonton
Prince Albert
Qu'Appelle
Winnipeg
Moose Jaw
Swift Current
Medicine Hat
Calgary
Banff
Kamloops
Victoria
Port Simpson
Dawson
Sitka
Salt Lake City
Miles City
Pierre
Huron
Duluth
White River
Cochrane
Port Arthur
Alpena
Toronto
Oswego
Kingston
Montreal
Quebec
Father Point
Halifax
Yarmouth
Portland
Boston
New York
Atlantic City
Washington
Lynchburg
Roanoke
Knoxville
Atlanta
Chattanooga
Montgomery
Vicksburg
Shreveport
Abilene
Amarillo
Santa Fe
Albuquerque
Durango
Phoenix
Tucson
El Paso
Del Rio
Brownsville
Corpus Christi
Laredo
Eagle Pass
Presidio
Mazatlan
Manzanillo
Acapulco
Salina Cruz
Tehuantepec
Progreso
Belize
Puerto Barrios
Puerto Cortez
Puerto Limon
Colon
Cristobal
Maracaibo
Curacao
Trinidad
Barbados
Grenada
St. Lucia
Martinique
Guadeloupe
Antigua
St. Kitts
Dominica
Porto Rico
Turks Island
Santo Domingo
Kingston
Swan I
Isle of Pines
Havana
Nassau
Key West
Tampa
Jacksonville
Charleston
Hatteras
Bermuda
Nantucket
Halifax
Sydney
Louisburg
Father Point
Quebec
Montreal
Oswego
Buffalo
Cleveland
Toledo
Detroit
Port Huron
Alpena
Duluth
Huron
Pierre
Miles City
Salt Lake City
Roseburg
Portland
Tatoosh I
Port Angeles
Seattle
Victoria
Port Simpson
Dawson
Sitka
Prince Rupert
Edmonton
Prince Albert
Qu'Appelle
Winnipeg
Moose Jaw
Swift Current
Medicine Hat
Calgary
Banff
Kamloops



E. H. B. **Fig. 1.—An old form of pressure-change map prepared by the U. S. Weather Bureau, a. m., July 8, 1915.**



E. H. B. Fig. 2.—An old form of pressure-change map prepared by the U. S. Weather Bureau, p. m., July 8, 1915.

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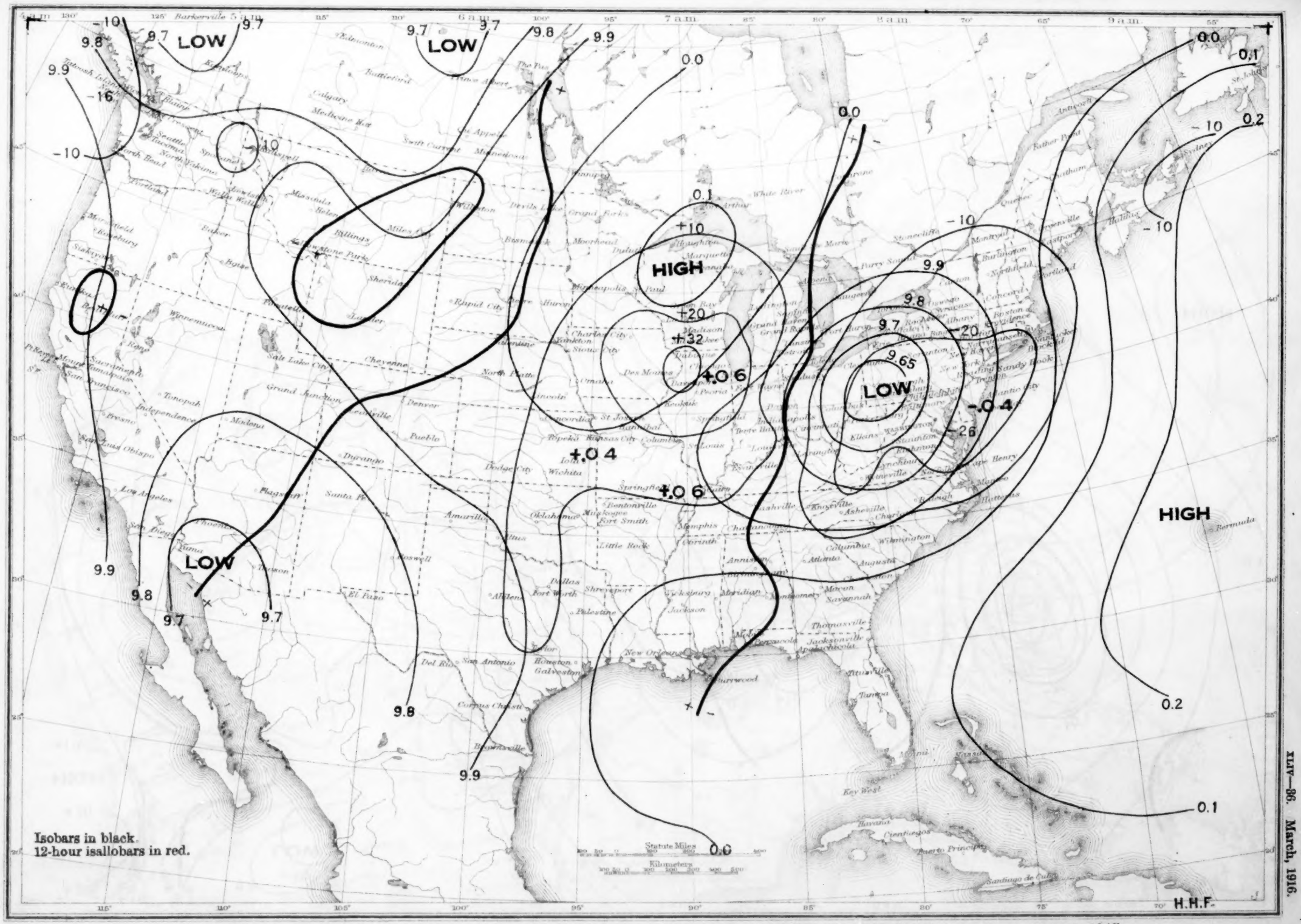
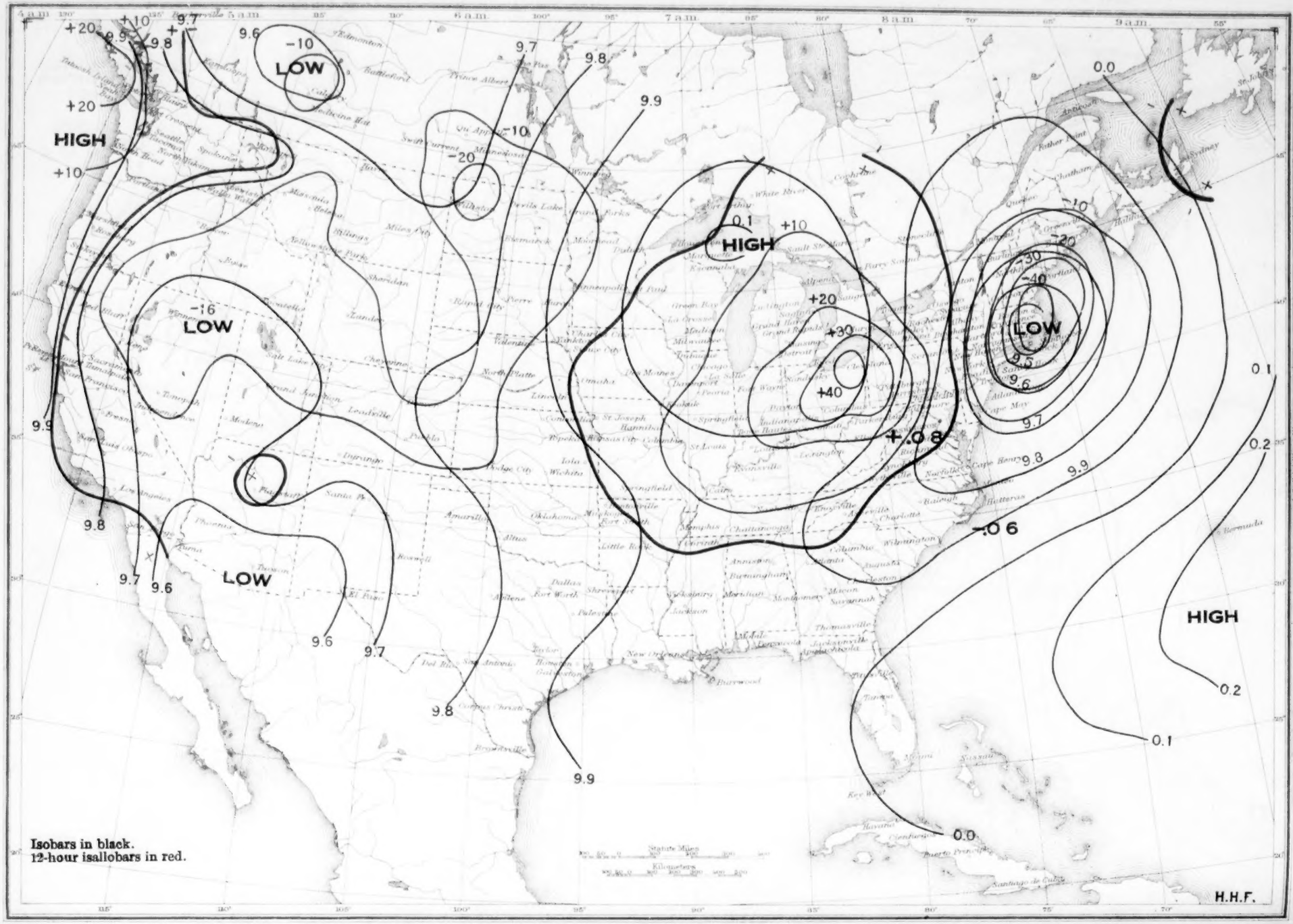


E. H. B. Fig. 3.—Illustration of the revised form of pressure-change map prepared by the U. S. Weather Bureau, a. m., July 8, 1915.

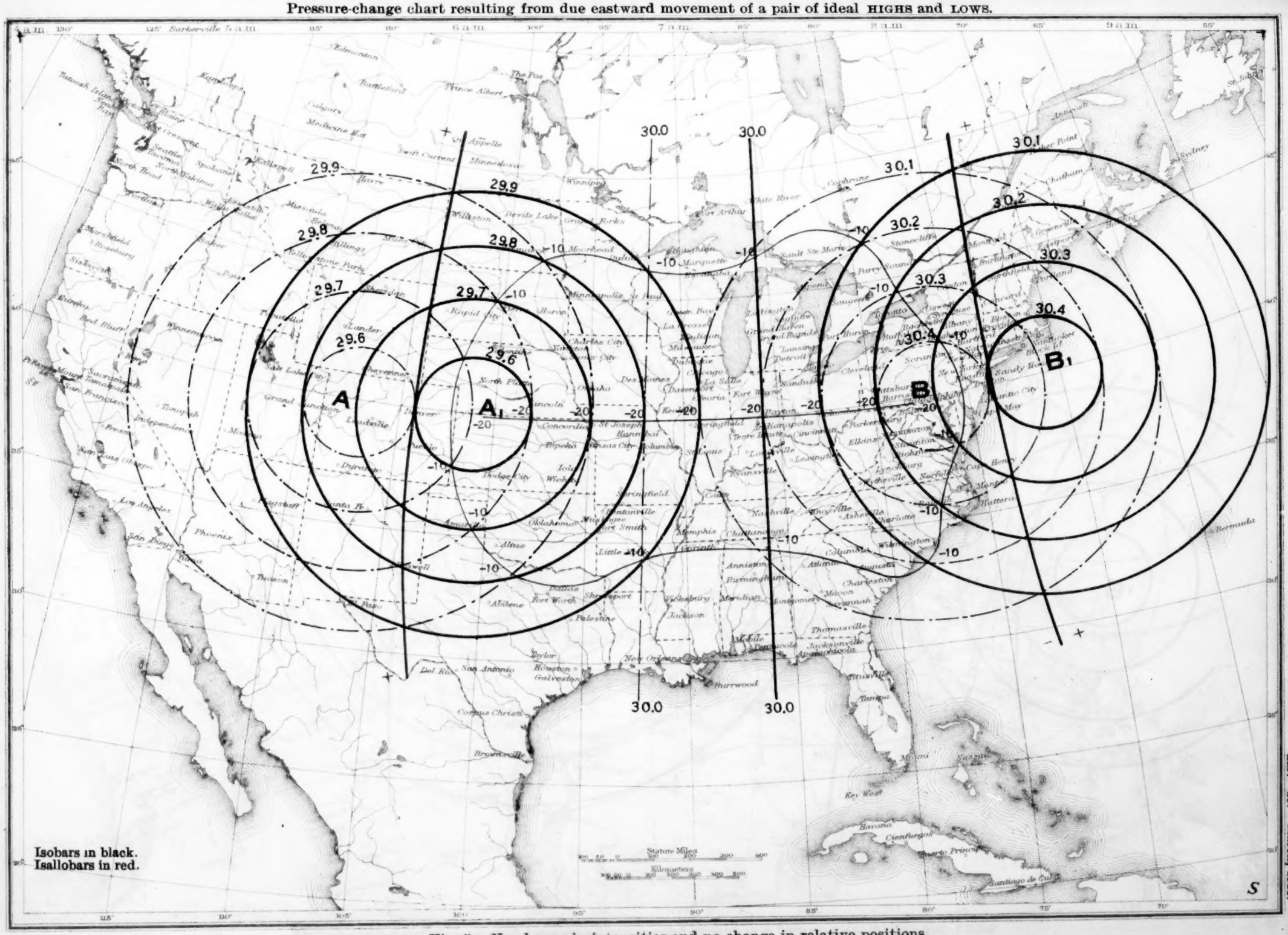


E. H. B. Fig. 4.—Illustration of the revised form of pressure-change map prepared by the U. S. Weather Bureau, p. m., July 8, 1915.

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.

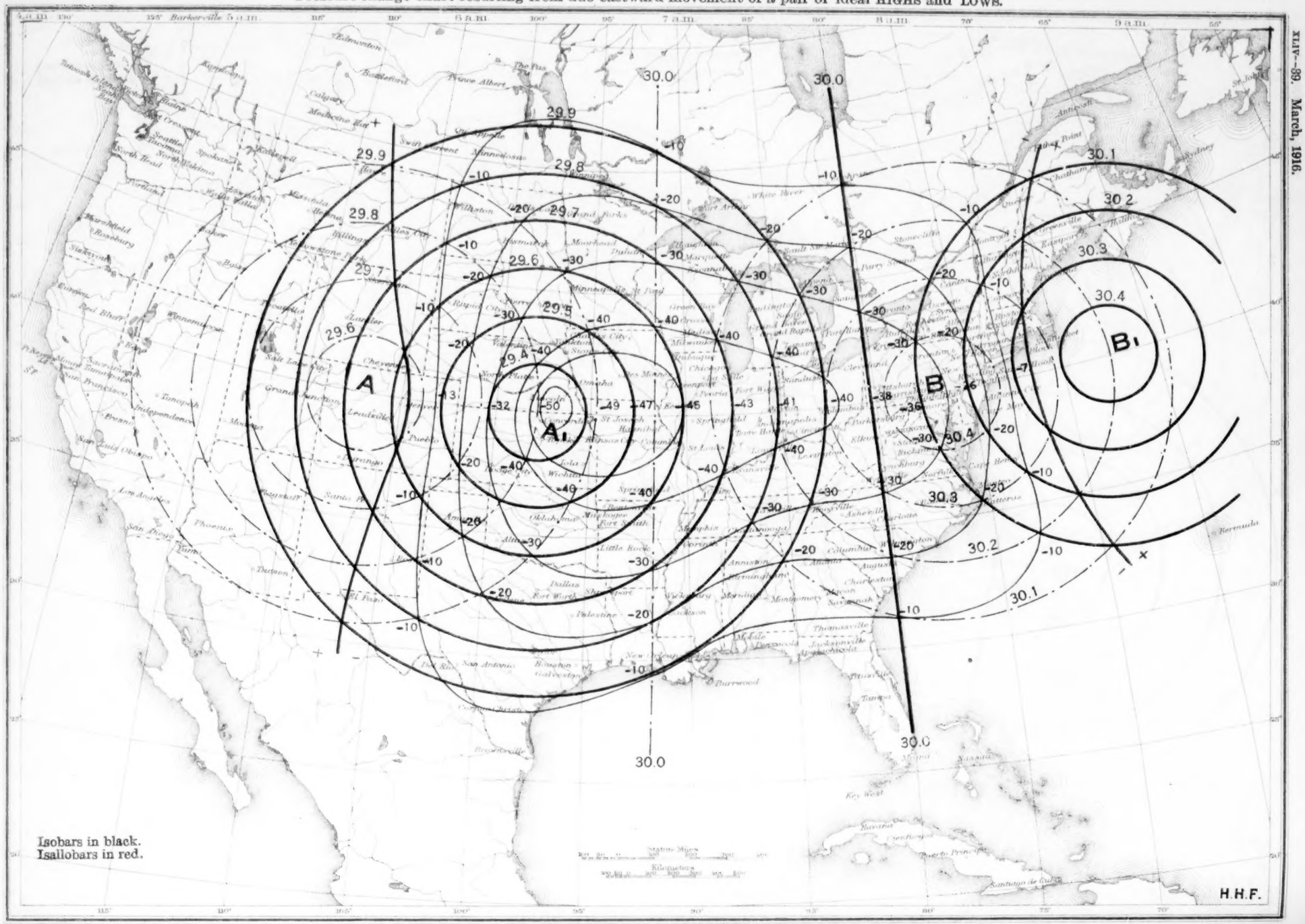
E. H. B. Fig. 4.—Illustration of the revised form of pressure-change map prepared by the U. S. Weather Bureau, p. m., July 8, 1915.

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.



E. H. B. Fig. 5.—No change in intensities and no change in relative positions..

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.

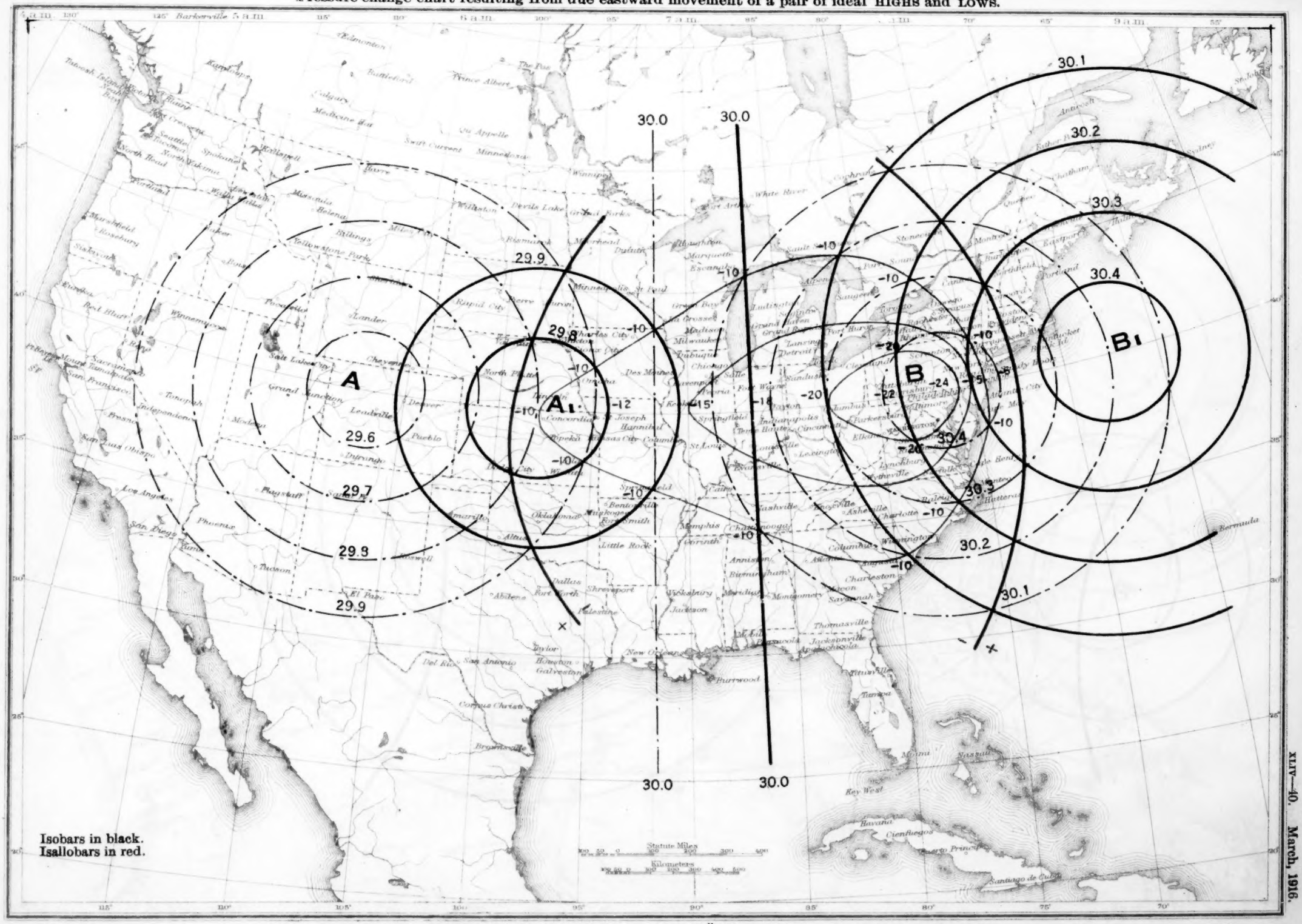


E. H. B. Fig. 6.—Pressure at the center of LOW falls 0.2″, distance between centers unchanged.

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.

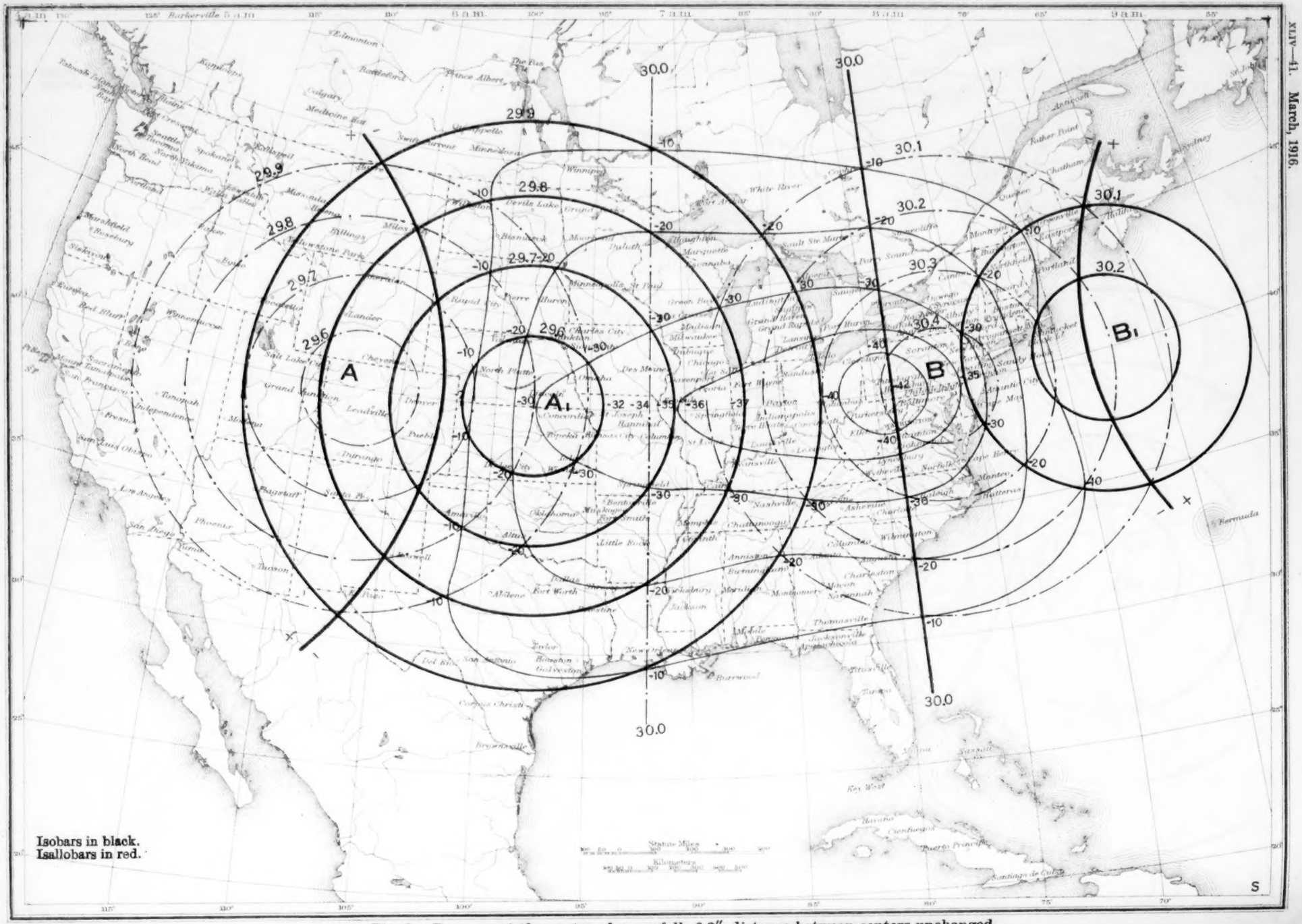
E. H. B. Fig. 6.—Pressure at the center of LOW falls 0.2″, distance between centers unchanged.

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.



E. H. B. Fig. 7.—Pressure at the center of LOW rises 0.2″, distance between centers unchanged.

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.



E. H. B. Fig. 8.—Pressure at the center of HIGH falls 0.2″, distance between centers unchanged.

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.

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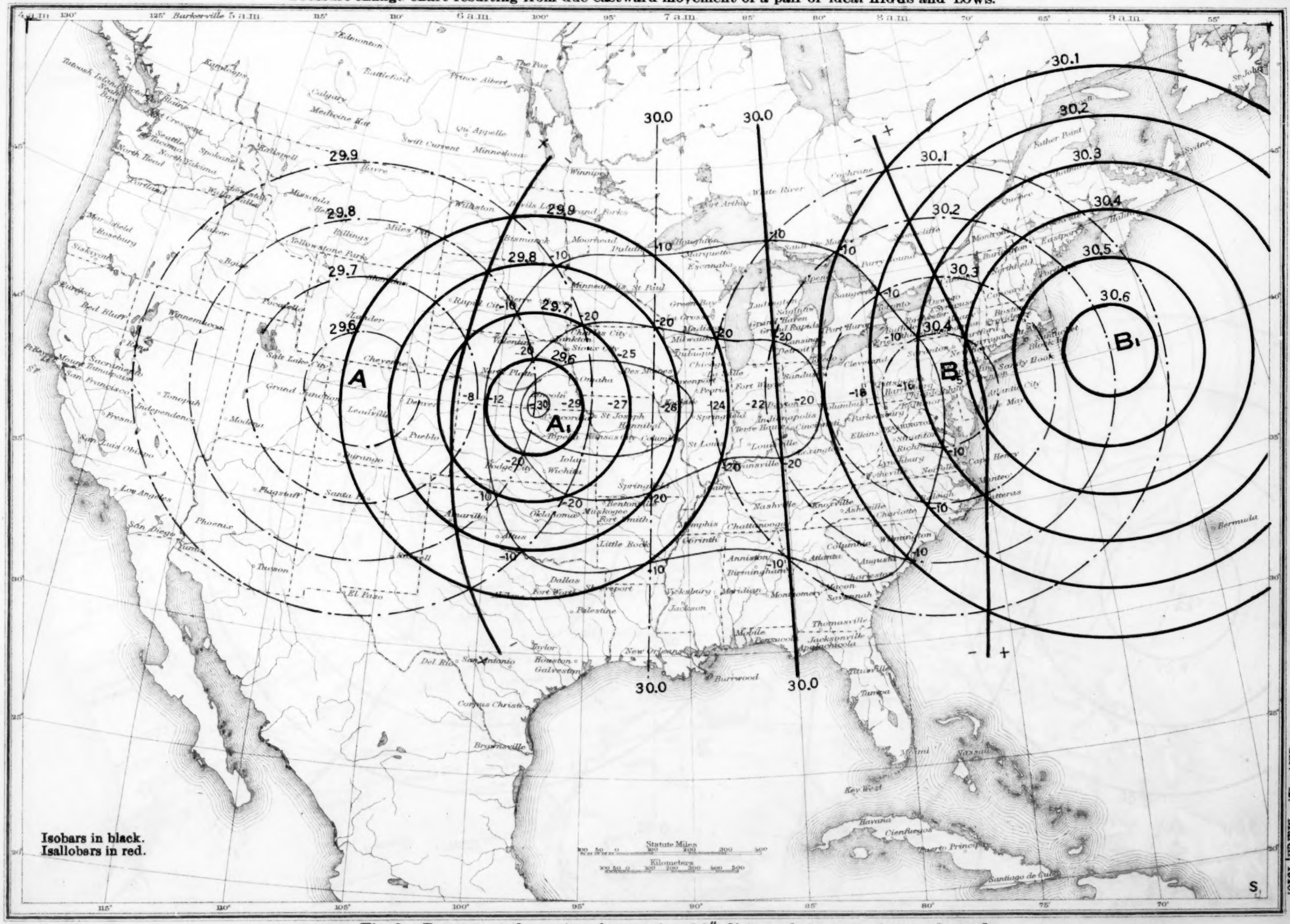
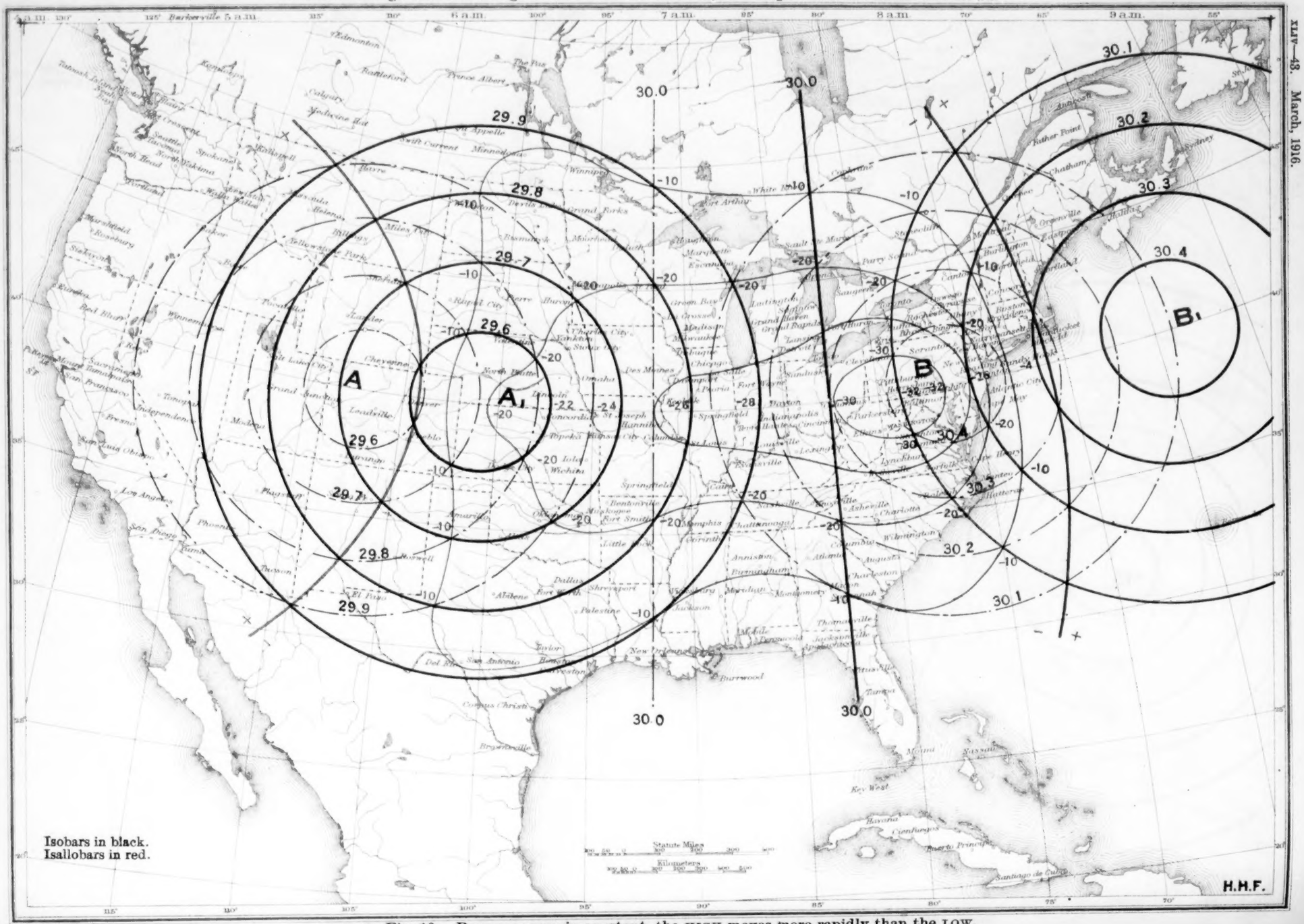
Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.



E. H. B. Fig. 9.—Pressure at the center of HIGH rises 0.2″, distance between centers unchanged.

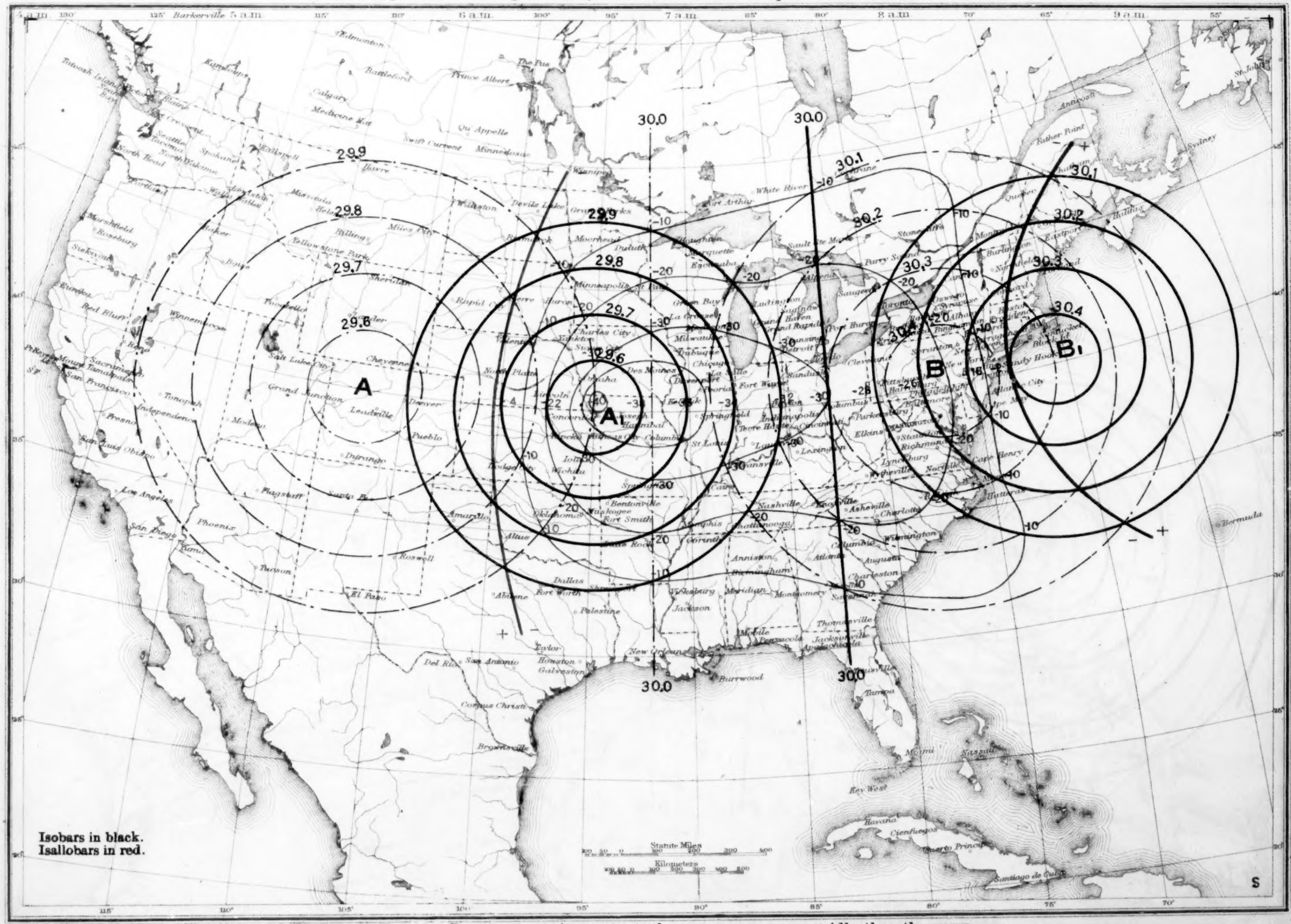
Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.



E. H. B. Fig. 10.—Pressures remain constant, the HIGH moves more rapidly than the LOW.

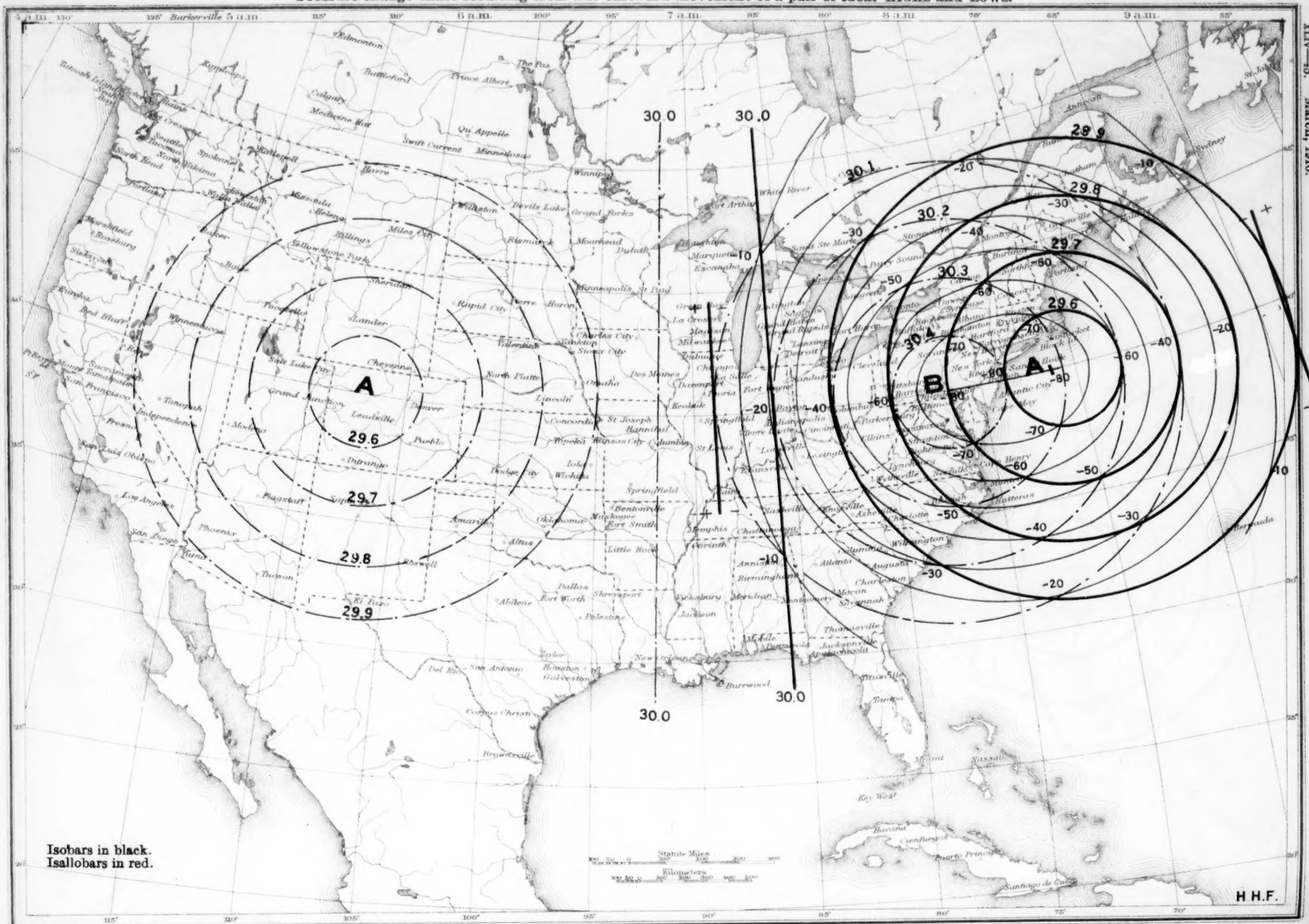
Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.



E. H. B. Fig. 11.—Pressures remain constant, the LOW moves more rapidly than the HIGH.

Pressure-change chart resulting from due eastward movement of a pair of ideal HIGHS and LOWS.



E. H. B. Fig. 12—Pressures remain constant, the LOW has moved so rapidly that its center has passed beyond the initial position of the HIGH.